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ABSTRACT

This Unified Sciences and Mathematics for Elementary Schools (USMES) unit challenges students to learn or teach someone certain things (spelling, geometry, metric system). The challenge is general enough to apply to many problem-solving situations in mathematics, science, social science, and language arts at any elementary school level (grades 1-8). The Teacher Resource Book for the unit is divided into five sections. Section I describes the USMES approach to student-initiated investigations of real problems, including a discussion of the nature of USMES "challenges." Section II provides an overview of possible student activities with comments on prerequisite skills, instructional strategies, suggestions when using the unit with primary grades, a flow chart illustrating how investigations evolve from students' discussions of teaching/learning problems, and a hypothetical account of intermediate-level class activities. Section III provides documented events of actual class activities from grades 2-5, 4, and 6-8. Section IV includes lists of "How To" cards and background papers, bibliography of non-USMES materials, and a glossary. Section V consists of charts identifying skills, concepts, processes, and areas of study learned as students become involved with activities in teaching/learning. (JN)

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Who ivented the telescope?
to find the answer look
in Colliers Encyclopedia
page 111 book 3

Ways to Learn/Teach

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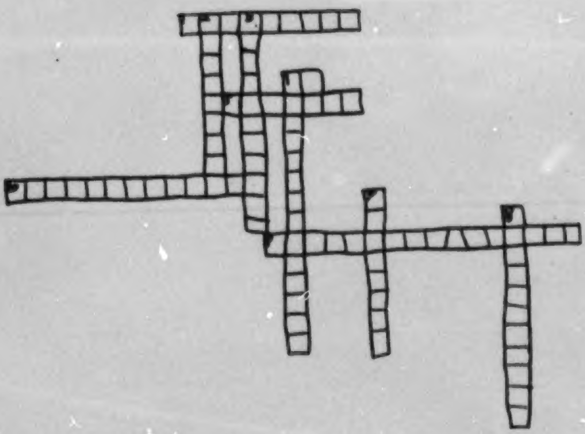

across

1. what did John Finch invent?
5 how does man invent?
6 who discovered vacine?
9 who invented the telescope?
4 (abbrebiate) Benjam Franklin

DOWN

2 what did Alexander Gram Bell discover?
3 who invented dynamite?
4. who inverted the stove?
7. what did the wright brothers invent?
8. who made the first movies?

SE 039 085

Teacher Resource Book

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This book is a resource developed by the USMES Project; Earl L. Lomon, Project Director; Betty M. Beck, Associate Director for Development Thomas L. Brown, Associate Director for Utilization Studies; Quinton E. Baker, Associate Director for Administration.

UNIFIED SCIENCES AND MATHEMATICS FOR ELEMENTARY SCHOOLS:
Mathematics and the Natural, Social, and Communications Sciences in
Real Problem Solving.

Ways to Learn/Teach

Third Edition

animal names

P K Z E B R A P y t a R P U Q a
A N I M A N a P 5 z m o n m
N N M T N T U P y e n p a u
D O t o o T N a U c z x o P e t
A o n D E l E P h a n t e a n P R
n a k n + n y + z x P l i o n
m p e p R D o g z x + s n p m
K e y a U t R U a x e t c a B y z

① Panda
② Kitten
③ ant
④ Zebra
⑤ Rat
⑥ Monkey
⑦ elephant
⑧ Dog
⑨ cat
⑩ Puppy
⑪ ape
⑫ lion

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Trial Edition

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CHALLENGE: FIND THE BEST WAY TO LEARN OR TO TEACH SOMEONE ELSE CERTAIN THINGS.

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Preface

The USMES Project

Unified Sciences and Mathematics for Elementary Schools: Mathematics and the Natural, Social, and Communications Sciences in Real Problem Solving (USMES) was formed in response to the recommendations of the 1967 Cambridge Conference on the Correlation of Science and Mathematics in the Schools.* Since its inception in 1970, USMES has been funded by the National Science Foundation to develop and carry out field trials of interdisciplinary units centered on long-range investigations of real and practical problems (or "challenges") taken from the local school/community environment. School planners can use these units to design a flexible curriculum for grades kindergarten through eight in which real problem solving plays an important role.

Development and field trials were carried out by teachers and students in the classroom with the assistance of university specialists at workshops and at occasional other meetings. The work was coordinated by a staff at the Education Development Center in Newton, Massachusetts. In addition, the staff at EDC coordinated implementation programs involving schools, districts, and colleges that are carrying out local USMES implementation programs for teachers and schools in their area.

Trial editions of the following units are currently available:

Advertising
Bicycle Transportation
Classroom Design
Classroom Management
Consumer Research
Describing People
Designing for Human Proportions
Design Lab Design
Eating in School
Getting There
Growing Plants
Manufacturing
Mass Communications
Nature Trails
Orientation
Pedestrian Crossings
Play Area Design and Use
Protecting Property
School Rules
School Supplies
School Zoo
Soft Drink Design
Traffic Flow
Using Free Time
Ways to Learn/Teach
Weather Predictions

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*See *Goals for the Correlation of Elementary Science and Mathematics*, Houghton Mifflin Co., Boston, 1969.

USMES Resources

In responding to a long-range challenge, the students and teachers often have need of a wide range of resources. In fact, all of the people and materials in the school and community are important resources for USMES activities. In addition USMES provides resources for both teachers and students. A complete set of all the written materials comprise the USMES library, which should be available in each school using USMES units. These materials include--

1. *The USMES Guide*: This book is a compilation of materials that may be used for long-range planning of a curriculum that incorporates the USMES program. It describes the USMES project, real problem solving, classroom strategies, the Design Lab, the units, and the support materials as well as ways that USMES helps students learn basic skills.

2. *Teacher Resource Books* (one for each challenge): Each of these guides to using USMES units describes a broad problem, explains how students might narrow that problem to fit their particular needs, recommends classroom strategies, presents edited logs from teachers whose classes have worked on the unit, and contains charts that indicate basic skills, processes, and areas of study that students may learn and utilize.

3. *Design Lab Manual*: This guide helps teachers and administrators set up, run, and use a Design Lab--a place with tools and materials in which the students can build things they need for their work on USMES. A Design Lab may be a corner of a classroom, a portable cart, or a separate room. Because many "hands-on" activities may take place in the classroom, every USMES teacher should have a Design Lab Manual.

4. *"How To" Series*: These student materials provide information to students about specific problems that may arise during USMES units. The regular *"How To" Series* covers problems in measuring, graphing, data handling, etc., and is available in two versions--a series of

cartoon-style booklets for primary grades and a series of magazine-style booklets with more reading matter for upper grades. The *Design Lab "How To" Series* is available in two illustrated card versions--one for primary grades and one for upper grades. A complete list of the *"How To" Series* can be found in the *USMES Guide*.

5. *Background Papers*: These papers, correlated with the *"How To" Series*, provide teachers with information and hints that do not appear in the student materials. A complete list can be found in the *USMES Guide*.

6. *Curriculum Correlation Guide*: By correlating the twenty-six USMES units with other curriculum materials, this book helps teachers to integrate USMES with other school activities and lessons.

The preceding materials are described in brief in the USMES brochure, which can be used by teachers and administrators to disseminate information about the program to the local community. A variety of other dissemination and implementation materials are also available for individuals and groups involved in local implementation programs. They include *Preparing People for USMES: An Implementation Resource Book*, the USMES slide/tape show, the Design Lab slide/tape show, the Design Lab brochure, videotapes of classroom activities, a general report on evaluation results, a map showing the locations of schools conducting local implementation of USMES, a list of experienced USMES teachers and university consultants, and newspaper and magazine articles.

* * * * *

Because Tri-Wall was the only readily available brand of three-layered cardboard at the time the project began, USMES has used it at workshops and in schools; consequently, references to Tri-Wall can be found throughout the Teacher Resource Books. The addresses of suppliers of three-layered cardboard can be found in the Design Lab Manual.

Introduction

Using the Teacher Resource Book

When teachers try a new curriculum for the first time, they need to understand the philosophy behind the curriculum. The USMES approach to student-initiated investigations of real problems is outlined in section A of this Teacher Resource Book.

Section B starts with a brief overview of possible student activities arising from the challenge; comments on prerequisite skills are included. Following that is a discussion of the classroom strategy for USMES real problem-solving activities, including introduction of the challenge, student activity, resources, and Design Lab use. Subsequent pages include a description of the use of the unit in primary grades, a flow chart and a composite log that indicate the range of possible student work, and a list of questions that the teacher may find useful for focusing the students' activities on the challenge.

Because students initiate all the activities in response to the challenge and because the work of one class may differ from that undertaken by other classes, teachers familiar with USMES need to read only sections A and B before introducing the challenge to students.

Section C of this book is the documentation section. These edited teachers' logs show the variety of ways in which students in different classes have worked at finding a solution to the challenge.

Section D contains a list of the titles of relevant sets of "How To" Cards and brief descriptions of the Background Papers pertaining to the unit. Also included in section D is a glossary of the terms used in the Teacher Resource Book and an annotated bibliography.

Section E contains charts that indicate the comparative strengths of the unit in terms of real problem solving, mathematics, science, social science, and language arts. It also contains a list of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in the unit. These charts and lists are based on documentation of activities that have taken place in USMES classes. Knowing ahead of time which basic skills and processes are likely to be utilized, teachers can postpone teaching that part of their regular program until later in the year. At that time students can study them in the usual way if they have not already learned them as part of their USMES activities.

A. Real Problem Solving and USMES

> *If life were of such a constant nature that there were only a few chores to do and they were done over and over in exactly the same way, the case for knowing how to solve problems would not be so compelling. All one would have to do would be to learn how to do the few jobs at the outset. From then on he could rely on memory and habit. Fortunately--or unfortunately depending upon one's point of view--life is not simple and unchanging. Rather it is changing so rapidly that about all we can predict is that things will be different in the future. In such a world the ability to adjust and to solve one's problems is of paramount importance.**

Real Problem Solving

USMES is based on the beliefs that real problem solving is an important skill to be learned and that many math, science, social science, and language arts skills may be learned more quickly and easily within the context of student investigations of real problems. Real problem solving, as exemplified by USMES, implies a style of education which involves students in investigating and solving real problems. It provides the bridge between the abstractions of the school curriculum and the world of the student. Each USMES unit presents a problem in the form of a challenge that is interesting to children because it is both real and practical. The problem is real in several respects: (1) the problem applies to some aspect of student life in the school or community, (2) a solution is needed and not presently known, at least for the particular case in question, (3) the students must consider the entire situation with all the accompanying variables and complexities, and (4) the problem is such that the work done by the students can lead to some improvement in the situation. This expectation of useful accomplishment provides the motivation for children to carry out the comprehensive investigations needed to find some solution to the challenge.

The level at which the children approach the problems, the investigations that they carry out, and the solutions that they devise may vary according to the age and ability of the children. However, real problem solving involves them, at some level, in all aspects of the problem-solving process: definition of the problem; determination of the important factors in the problem; observation; measurement; collection of data; analysis of the data using graphs, charts, statistics, or whatever means the students can find; discussion; formulation and trial of suggested solutions; clarification of values; decision making; and communications of findings to others. In addition, students become more inquisitive, more cooperative in working with others, more critical in their thinking, more self-reliant, and more interested in helping to improve social conditions.

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*Kenneth B. Henderson and Robert E. Pingry, "Problem-Solving in Mathematics," in *The Learning of Mathematics: Its Theory and Practice*, Twenty-first Yearbook of the National Council of Teachers of Mathematics (Washington, D.C.: The Council, 1953), p. 233.

The USMES Approach

To learn the process of real problem solving, the students must encounter, formulate, and find some solution to complete and realistic problems. The students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of their hypotheses and conclusions. In real problem-solving activities, the teacher acts as a coordinator and collaborator, not an authoritative answer-giver.

The problem is first reworded by students in specific terms that apply to their school or community, and the various aspects of the problem are discussed by the class. The students then suggest approaches to the problem and set priorities for the investigations they plan to carry out. A typical USMES class consists of several groups working on different aspects of the problem. As the groups report periodically to the class on their progress, new directions are identified and new task forces are formed as needed. Thus, work on an USMES challenge provides students with a "discovery-learning" or "action-oriented" experience.

Real problem solving does not rely solely on the discovery-learning concept. In the real world people have access to certain facts and techniques when they recognize the need for them. The same should be true in the classroom. When the students find that certain facts and skills are necessary for continuing their investigation, they learn willingly and quickly in a more directed way to acquire these facts and skills. Consequently, the students should have available different resources that they may use as they recognize the need for them, but they should still be left with a wide scope to explore their own ideas and methods.

Certain information on specific skills is provided by the sets of USMES "How To" Cards. The students are referred only to the set for which they have clearly identified a need and only when they are unable to proceed on their own. Each "How To" Cards title clearly indicates the skill involved--"How to Use a Stopwatch," "How to Make a Bar Graph Picture of Your Data," etc. (A complete list of the "How To" Cards can be found in Chapter IX of the USMES Guide.)

Another resource provided by USMES is the Design Lab or its classroom equivalent. The Design Lab provides a central location for tools and materials where devices may be constructed and tested without appreciably disrupting other classroom activities. Ideally, it is a separate room with space for all necessary supplies and equipment and work space for the children. However, it may be as small as a corner of the classroom and may contain only a few tools and supplies. Since the benefits of real problem solving can be obtained by the students only if they have a means to follow up their ideas, the availability of a Design Lab can be a very important asset.

Optimally, the operation of the school's Design Lab should be such as to make it available to the students whenever they need it. It should be as free as possible from set scheduling or programming. The students use the Design Lab to try out their own ideas and/or to design, construct, test, and improve many devices initiated by their responses to the USMES challenges. While this optimum operation of the Design Lab may not always be possible due to various limitations, "hands-on" activities may take place in the classroom even though a Design Lab may not be available. (A detailed discussion of the Design Lab can be found in Chapter VI of the USMES Guide, while a complete list of "How To" Cards covering such Design Lab skills as sawing, gluing, nailing, soldering, is contained in Chapter IX.)

Work on all USMES challenges is not only sufficiently complex to require the collaboration of the whole class but also diverse enough to enable each student to contribute according to his/her interest and ability. However, it should be noted that if fewer than ten to twelve students from the class are carrying out the investigation of a unit challenge, the extent of their discovery and learning can be expected to be less than if more members of the class are involved. While it is possible for a class to work on two related units at the same time, in many classes the students progress better with just one.

The amount of time spent each week working on an USMES challenge is crucial to a successful resolution of the problem. Each challenge is designed so that the various investigations will take from thirty to forty-five hours, depending on the age of the children, before some solution to the problem is found and some action is taken on the results of the investigations. Unless sessions are held at least two or three times a week, it is difficult for the children to maintain their interest and momentum and to become involved intensively with the challenge. The length of each session depends upon the age level of the children and the nature of the challenge. For example, children in the primary grades may proceed better by working on the challenge more frequently for shorter periods of time, perhaps fifteen to twenty minutes, while older children may proceed better by working less frequently for much longer periods of time.

Student interest and the overall accomplishments of the class in finding and implementing solutions to the challenge indicate when the class's general participation in unit activities should end. (Premature discontinuance of work on a specific challenge is often due more to waning interest on the part of the teacher than to that of the students.) However, some students may continue work on a voluntary basis on one problem, while the others begin to identify possible approaches to another USMES challenge.

Importance of the Challenge

Although individual (or group) discovery and student initiation of investigations is the process in USMES units, this does not imply the constant encouragement of random activity. Random activity has an important place in children's learning, and opportunities for it should be made available at various times. During USMES activities, however, it is believed that children learn to solve real problems only when their efforts are focused on finding some solution to the real and practical problem presented in the USMES challenge. It has been found that students are motivated to overcome many difficulties and frustrations in their efforts to achieve the goal of effecting some change or at least of providing some useful information to others. Because the children's commitment to finding a solution to the challenge is one of the keys to successful USMES work, it is extremely important that the challenge be introduced so that it is accepted by the class as an important problem to which they are willing to devote a considerable amount of time.

The challenge not only motivates the children by stating the problem but also provides them with a criterion for judging their results. This criterion--if it works, it's right (or if it helps us find an answer to our problem, it's a good thing to do)--gives the children's ideas and results a meaning within the context of their goal. Many teachers have found this concept to be a valuable strategy that not only allows the teacher to respond positively to all of the children's ideas but also helps the children themselves to judge the value of their efforts.

Role of the Teacher

With all of the above in mind, it can be said that the teacher's responsibility in the USMES strategy for open classroom activities is as follows:

1. Introduce the challenge in a meaningful way that not only allows the children to relate it to their particular situation but also opens up various avenues of approach.

2. Act as a coordinator and collaborator. Assist, not direct, individuals or groups of students as they investigate different aspects of the problem.

3. Hold USMES sessions at least two or three times a week so that the children have a chance to become involved in the challenge and carry out comprehensive investigations.

4. Provide the tools and supplies necessary for initial hands-on work in the classroom or make arrangements for the children to work in the Design Lab.

5. Be patient in letting the children make their own mistakes and find their own way. Offer assistance or point out sources of help for specific information (such as the "How To" Cards) only when the children become frustrated in their approach to the problem. Conduct skill sessions as necessary.

6. Provide frequent opportunities for group reports and student exchanges of ideas in class discussions. In most cases, students will, by their own critical examination of the procedures they have used, improve or set new directions in their investigations.

7. If necessary, ask appropriate questions to stimulate the students' thinking so that they will make more extensive and comprehensive investigations or analyses of their data.

8. Make sure that a sufficient number of students (usually ten to twelve) are working on the challenge so that activities do not become fragmented or stall.

Student success in USMES unit activities is indicated by the progress they make in finding some solution to the challenge, not by following a particular line of investigation nor by obtaining specified results. The teacher's role in the USMES strategy is to provide a classroom atmosphere in which all students can, in their own way, search out some solution to the challenge.

USMES in the Total School Program

Today many leading educators feel that real problem solving (under different names) is an important skill to be learned. In this mode of learning particular emphasis is placed on developing skills to deal with real problems rather than the skills needed to obtain "correct" answers to contrived problems. Because of this and because of the interdisciplinary nature of both the problems and the resultant investigations, USMES is ideal for use as an important part of the elementary school program. Much of the time normally spent in the class on the traditional approaches to math, science, social science, and language arts skills can be safely assigned to USMES activities. In fact, as much as one-fourth to one-third of the total school program might be allotted to work on USMES challenges. Teachers who have worked with USMES for several years have each succeeding year successfully assigned to USMES activities the learning of a greater number of traditional skills. In addition, reports have indicated that students retain for a long time the skills and concepts learned and practiced during USMES activities. Therefore, the time normally spent in reinforcing required skills can be greatly reduced if these skills are learned and practiced in the context of real problem solving.

Because real problem-solving activities cannot possibly cover all the skills and concepts in the major subject areas, other curricula as well as other learning modes (such as "lecture method," "individual study topics," or programmed instruction) need to be used in conjunction with USMES in an optimal education program. However, the other instruction will be enhanced by the skills, motivation, and understanding provided by real problem solving, and, in some cases, work on an USMES challenge provides the context within which the skills and concepts of the major subject areas find application.

In order for real problem solving taught by USMES to have an optimal value in the school program, class time should be apportioned with reason and forethought, and the sequence of challenges investigated by students during their years in elementary school should involve them in a variety of skills and processes. Because all activities are initiated by students in response to the challenge, it is impossible to state unequivocally which activities will take place. However, it is possible to use the documentation of activities that have taken place in USMES trial classes to schedule instruction on the specific skills and processes required by the school system. Teachers can postpone the traditional way of teaching the skills that might come up in work on an USMES challenge until later in the year. At that time students can learn the required skills in the usual way if they have not already learned them during their USMES activities.

These basic skills, processes, and areas of study are listed in charts and lists contained in each Teacher Resource Book. A teacher can use these charts to decide on an overall allocation of class time between USMES and traditional learning in the major subject disciplines. Examples of individual skills and processes are also given so that the teacher can see beforehand which skills a student may encounter during the course of his investigations. These charts and lists may be found in section E.

Ways In Which USMES Differs From Other Curricula

As the foregoing indicates, USMES differs significantly from other curricula. Real problem solving develops the problem-solving ability of students and does it in a way (learning-by-doing) that leads to a full understanding of the process. Because of the following differences, some teacher preparation is necessary. Some teachers may have been introduced by other projects to several of the following new developments in education, but few teachers have integrated all of them into the new style of teaching and learning that real problem solving involves.

1. New Area of Learning--Real problem solving is a new area of learning, not just a new approach or a new content within an already-defined subject area. Although many subject-matter curricula

include something called problem solving, much of this problem solving involves contrived problems or fragments of a whole situation and does not require the cognitive skills needed for the investigation of real and practical problems. Learning the cognitive strategy required for real problem solving is different from other kinds of learning.

3. Interdisciplinary Education--Real problem solving integrates the disciplines in a natural way; there is no need to impose a multi-disciplinary structure. Solving real and practical problems requires the application of skills, concepts, and processes from many disciplines. The number and range of disciplines are unrestricted and the importance of each is demonstrated in working toward the solution of practical problems.

3. Student Planning--To learn the process of problem solving, the students themselves, not the teacher, must analyze the problem, choose the variables that should be investigated, search out the facts, and judge the correctness of the hypotheses and conclusions. In real problem-solving activities the teacher acts as a coordinator and collaborator, not as an authoritative source of answers.

4. Learning-by-Doing--Learning-by-doing, or discovery learning as it is sometimes called, comes about naturally in real problem solving since the problems tackled by each class have unique aspects; for example, different lunchrooms or pedestrian crossings have different problems associated with them and, consequently, unique solutions. The challenge, as defined in each situation, provides the focus for the children's hands-on learning experiences, such as collecting real data; constructing measuring instruments, scale models, test equipment, etc.; trying their suggested improvements; and (in some units) preparing reports and presentations of their findings for the proper authorities.

5. Learning Skills and Concepts as Needed--Skills and concepts are learned in real problem solving

as the need for them arises in the context of the work being done, rather than having a situation imposed by the teacher or the textbook being used. Teachers may direct this learning when the need for it arises, or students may search out information themselves from resources provided.

6. Group Work--Progress toward a solution to a real problem usually requires the efforts of groups of students, not just individual students working alone. Although some work may be done individually, the total group effort provides good opportunities for division of labor and exchange of ideas among the groups and individuals. The grouping is flexible and changes in order to meet the needs of the different stages of investigation.

7. Student Choice--Real problem solving offers classes the opportunity to work on problems that are real to them, not just to the adults who prepare the curriculum. In addition, students may choose to investigate particular aspects of the problem according to their interest. The variety of activities ensuing from the challenge allows each student to make some contribution towards the solution of the problem according to his or her ability and to learn specific skills at a time when he or she is ready for that particular intellectual structure.

B. General Papers on Ways to Learn/Teach

1. OVERVIEW OF ACTIVITIES

Challenge:

Find the best way to learn or to teach someone else certain things.

Possible Class Challenges:

Find the best way to learn our weekly spelling words.

Find the best way to learn geometry.

Find the best way to teach another class about the metric system.

Learning is what school is all about, and students are usually eager to voice their opinions on the best ways to learn. Such a discussion may arise naturally as a class begins to study a new topic--a weekly spelling list, the metric system, the weather. A list of learning methods may be compiled by the class, and two or three selected for chosen investigation. When the teacher asks how they will determine which of the methods is most effective for learning the new topic, the students may see the need for pretests and posttests to use in evaluating their progress.

Students usually form several groups, each using one particular technique--games, audiovisuals, reading and research, practical application, memorization, etc. Individual abilities vary, and some children may be concerned that one group will have most of the fast learners, and thus an unfair advantage. To balance group memberships, the children may use results of the pretest given to the entire class or grades from the previous reporting period.

Each group then spends several sessions using their designated method to learn the new topic. Later the posttest is taken and the data assembled. Group differences from pretest to posttest may be calculated as total number of points gained (or lost) or total percentage gained; the gain in average group scores may also be determined. By depicting the data graphically, the class can more easily compare the progress of the groups and thus assess the effectiveness of the different methods. In older classes a statistical test may be used to determine whether there is a significant difference in results.

In discussing their experiment, the children may point out that retention is also an effective indicator of the effectiveness of learning. A third test on the topic may be scheduled for a date several weeks or one or two months later.

Some classes may be interested in finding out which method is most effective for each student. By exchanging methods, the groups can repeat the investigation to learn a new list of spelling words or another math topic. Data from both studies may then be used to make comparisons for individuals. The additional information gathered would also help in evaluating the overall effectiveness of each method since it would have been tried by several groups.

Children may also decide to find out whether their "best" learning method would be best for another subject. Class discussion may naturally turn to the relationship between the purpose for learning a topic and the methods used to learn it.

Some classes may focus on the teaching aspect of the unit. Their challenge may be a continuation of their own investigations of learning methods, or it may arise after a class has studied a new topic they feel their schoolmates would like to learn. The children use materials which they have developed for the different methods and then usually work in groups to teach another class. Pretest and posttest results are compared and analyzed to find the most effective method.

Although many of these activities may require skills and concepts new to the children, there is no need for preliminary work on these skills and concepts because the children can learn them when the need arises. In fact, children learn more quickly and easily when they see a need to learn. Consider counting: whereas children usually learn to count by rote, they can, through USMES, gain a better understanding of counting by learning or practicing it within real contexts. In working on Ways to Learn/Teach, children also learn and practice graphing, working with decimals, and dividing. Although dividing seems necessary to compare fractions or ratios, primary children can make comparisons graphically; sets of data can also be compared graphically or by subtracting medians (half-way values). Division may be introduced during calculation of percentages or averages.

2. CLASSROOM STRATEGY FOR WAYS TO LEARN/TEACH

Ways to Learn/Teach is centered on a challenge—a statement that says, "Solve this problem". Its success or failure in a classroom depends largely on (1) the relevance of the problem for the students and (2) the process by which they define and accept the challenge. If the children see the problem as a real one, they will be committed to finding a solution; they will have a focus and purpose for their activities. If the students do not think the problem affects them, their attempts at finding solutions will likely be disjointed and cursory.

The Ways to Learn/Teach challenge--"Find the best way to learn or to teach someone else certain things"--is general enough to apply to many situations. Students in different classes define and reword the challenge and thus arrive at a specific class challenge. For example, "Find the best way to learn our weekly spelling words" might be the challenge in one class, while a class that has just completed a unit on the metric system might have the challenge, "Find the best way to teach the class next door about the metric system."

The Process of Introducing the Challenge

Given that a problem exists, how can a teacher, without being directive, help the students identify the challenge that they will work on as a group? There is no set method because of variations among teachers, classes, and schools and among the USMES units themselves. However, USMES teachers have found that certain general techniques in introducing the challenge are helpful.

One such technique is to turn a discussion of some recent event toward a Ways to Learn/Teach challenge. For example, student complaints of boredom with the regular class routine could lead to a discussion of ways the children like to learn and which way they think is best. The challenge may also arise naturally whenever the class begins or concludes the study of a topic in any of the subject areas.

> *An eighth-grade math class began their investigations of the Ways to Learn/Teach challenge when they were asked to determine the best way to learn their next math topic--percentage. Many suggestions were offered by the children, and after extensive discussion they decide to work in small groups to investigate the effectiveness of four learning methods: learning centers, games, tapes and films, and business application.*

A Ways to Learn/Teach challenge may be an outgrowth of the children's work on another USMES unit. For example, a class investigating a Classroom Design challenge may think that the physical environment of the classroom has a direct effect on learning and then decide to conduct an experiment using different physical environments.

When children working on another USMES challenge encounter a problem that leads to a Ways to Learn/Teach challenge, one group of children may begin work on this second challenge while another continues on the first. However, there

> *In another intermediate class a very broad topic was chosen by majority vote, but no discussions were held regarding which particular aspects would be learned. After the students had begun working in groups using different learning methods, it soon became apparent that the groups were learning different things with little common ground. When one student mentioned this problem after the posttest was taken, everyone realized that the results would be biased toward those groups who happened to learn items appearing on the test. The students felt discouraged with their experiment and could see little value in interpreting data.*

Progress on the Ways to Learn/Teach challenge may also be hindered if the teacher, rather than ensuring that the children have agreed upon a challenge, merely assigns a series of activities. Although the teacher may see how these activities relate to an overall goal, the children may not.

> *An intermediate level teacher instructed his students to find the best way to learn a topic he had selected. By the second day of work student interest was already low. Several sessions were spent in random activities, but the teacher realized by the fifth day that the students lacked motivation. He called the groups together to discuss the problem and the class voted to discontinue work on the challenge.*

nitial Work on the Challenge

Once a class has decided to work on a Ways to Learn/Teach challenge, USMES sessions should be held several times a week, but they need not be rigidly scheduled. When sessions are held after long intervals, students often have difficulty remembering exactly where they were in their investigations, and momemtum diminishes.

During the initial session, after deciding on a topic to learn or to teach, children often list various learning methods, and the list may be long. By combining similar methods, they can choose two or three to work on first. If the students try to experiment with too many methods at once, their investigations will be superficial.

should be at least ten or twelve students working on any one challenge; otherwise the children's work may be fragmented or superficial or may break down completely.

Sometimes the discussion of a broad problem may encompass the challenges of several related units. For example, a discussion of problems at school could lead to Eating in School, Classroom Management, Classroom Design, School Rules, or Ways to Learn/Teach, depending on which problems the children identify.

An experienced USMES teacher is usually willing to have the children work on any one of the several challenges that may arise during the discussion of a broad problem. While this approach gives the children the opportunity to select the challenge they are most interested in investigating, it does place on the teacher the additional responsibility of being prepared to act as a resource person for whichever challenge is chosen.

Classroom experience has shown that children's progress on a Ways to Learn/Teach challenge may be poor if the teacher and students do not reach a common understanding of what the challenge is before beginning work on it. Having no shared focus for their work, the children will lack the motivation inherent in working together to solve a real problem. As a result, they may quickly lose interest.

A similar situation occurs when a class investigates learning or teaching a very broad topic or tries to learn or to teach many topics at a time.

Preliminary investigations of the Ways to Learn/Teach challenge were carried out by a sixth-grade class in response to the challenge, "Find the best way to learn something you need and want to learn." Children worked in small groups or on an individual basis to improve such things as drawing, model building, dart throwing and speed reading. The breadth of topics considered at the same time resulted in fragmented activities and superficial investigations. Early diagnosis of the problem by the teacher enabled him to help the children narrow the scope of their investigations to learning spelling words. The children worked in six groups, using a different learning method. Later as time and the children's interest directed, other applications were explored. As a result of limiting the directions taken at any given time, more comprehensive investigations were taken and the children's involvement increased.

Students usually form groups to try out different learning methods. However, if too many groups are formed, work on the challenge can become fragmented. The teacher finds it impossible to be aware of the progress and problems of each group; in addition, the small number of students in each group lessens the chance for varied input and interaction and decreases the possibility that a comparison among learning methods will be meaningful.

Refocusing on the Challenge

As children work on a Ways to Learn/Teach challenge, their attention should, from time to time, be refocused on that challenge so that they do not lose sight of their overall goal. Refocusing is particularly important with younger children because they have a shorter attention span. Teachers find it helpful to hold periodic class discussions that include group reports. Such sessions help the students review what they have accomplished and what they still need to do.

> *Seventh-grade students began an investigation of the Ways to Learn/Teach challenge as they prepared to begin a new mathematics topic--geometry. Frequent class discussions about their progress and setbacks enabled them to plan an improved course of action. Instead of determining the best way to learn geometry by trying different methods themselves, they decided to redirect their investigations and use different methods to teach geometry to students in another class.*

Resources for Work on the Challenge

When children try to decide on solutions before collecting and analyzing enough data or encounter difficulties during their investigations, an USMES teacher helps out. But instead of giving answers or suggesting specific procedures, the teacher asks open-ended questions that stimulate the students to think more comprehensively and creatively about their work. For example, instead of telling students that they should schedule pretests and posttests to collect data for evaluating learning methods, the teacher might ask, What kind of information will we need to find out which is the most effective method? How will we collect this information?" Examples of other nondirective, thought-provoking questions are given in section B-6.

The teacher may also refer students to the "How To" Cards, which provide information about specific skills, such as drawing graphs. If many students, or even the entire class, need help in particular areas, such as using fractions, the teacher should conduct skill sessions as these needs arise. (Background Papers provide teachers with additional information and on general topics applicable to the Ways to Learn/Teach challenge.)

USMES teachers can also assist students by making it possible for them to carry out tasks involving hands-on activities. If the children's tasks require them to design and construct items, such as Tri-Wall alphabet letters or a learning "machine," the teacher should make sure that they have access to a Design Lab—any collection of tools and materials kept in a central location (in part of the classroom, on a portable cart, or in a separate room). A more detailed description of the Design Lab may be found in the USMES Guide.

Valuable as it is, a Design Lab is not necessary to begin work on Ways to Learn/Teach. The Design Lab is used only when needed, and, depending on the investigations chosen by the children, the need may not arise at all.

In trying to find the best of three methods for learning math, one class of primary students worked with materials in their classroom. The children played math games, completed worksheets, and worked with manipulative objects, such as a number line, and had no need for a Design Lab.

Children in one sixth-grade class became involved in the Ways to Learn/Teach challenge through discussions of ways to learn about the metric system. Although the school did have a fully equipped Design Lab, the children were able to complete their investigations within their own classroom. Prestudy tests were taken, groups were formed, and work was completed by the children before the post-study test was taken and the data were compiled and compared.

Culminating Activities

Student investigations on Ways to Learn/Teach generally continue until the children agree they have an acceptable solution to the challenge. The class may decide which method is best for short-range learning based on a comparison of the changes between pretests and posttests. They may also check on which way is best by comparing changes between pretests and retention tests. These comparisons may be made by using graphs or simple statistics. (A more rigorous statistical test may be used by older students.) If the results are inconclusive, the class may conduct a survey to find out which way was liked the most by the students. To check on individual differences, they might use the same methods to learn another topic and compare the results of both experiments.

3. USE OF WAYS TO LEARN/TEACH IN THE PRIMARY GRADES

Having an opportunity to direct their own learning or to teach other students is an exciting prospect for primary children. They enjoy the responsibility and freedom of experimenting with different learning techniques, and they are usually eager to play "teacher" and share their knowledge with other students. If two classes are simultaneously working on the Ways to Learn/Teach challenge, each class may have a different topic and be teachers for one topic and learners for the other one.

An introduction to a new topic or children's complaints of boredom with the usual classroom routine present an ideal time to introduce the challenge. A lively discussion may follow the teacher's question, "Can we find an interesting way to learn this subject that's better than any other way?" As suggestions are made, they may be listed on the board--games, worksheets, manipulative objects, audiovisuals, practice, copying, etc.

To decide on two or three methods they will try out, the children usually vote. When the list is long, each child can have two or three votes.

The children allow a certain amount of time, perhaps one or two weeks, to study the topic in their groups. If they are preparing materials themselves, they will need additional time. Children working on games may develop board games or card games, while a practice group might make worksheets or set up activities using manipulative objects such as blocks. Members of an audiovisual group may record cassette tapes to go with drawings and pictures or they might borrow related films and filmstrips from the library. Students in a book group might devise lists directing children to pages of different books, or they might prepare a booklet of information they have mimeographed.

Because young children have short attention spans, frequent class discussions, held perhaps at the beginning of each USMES session, help them stay on track. During these discussions teachers often ask how their work is helping them meet the challenge. Group reporting also gives children a chance to help each other with problems and allows everyone to contribute to decision making and planning--"Now that we've heard from the different groups, what should we do now?"

Either the teacher or the children may grade the posttests. When the data are collected, a class meeting is held to discuss what to do with them. By subtracting pretest scores from posttest scores, the children can find out how much each person gained (or the reverse procedure may be used for a decrease in points). They then compare the total number of points gained by each group. If the children have difficulty comparing the size of numbers, they can construct a bar graph and compare the heights of the bars.

When groups have different numbers of members, the children may point out that larger groups will naturally have larger total scores. The teacher can explain how to find an average group score and help the children with the division.

Comparing group averages can also be done without dividing. The children can be shown how to draw a slope diagram, plotting the size of each group against the total number of points gained (see example in Glossary). By comparing the steepness of the lines, the children can rank the groups according to their average scores; the steeper the line, the higher the average score.

Now experiments may be conducted as often as the children wish. Groups may exchange methods or new groups may be formed. The children may use a new set of spelling words, new math problems, or another science topic, or they may try their methods with a completely different subject. For the final evaluation, a simple survey may be devised to find the best-liked method. Data may be directly tallied onto a bar graph simply by stacking blocks or making tally marks in labeled columns. The children may also present their findings to other teachers and encourage them to use the most successful methods with their classes.

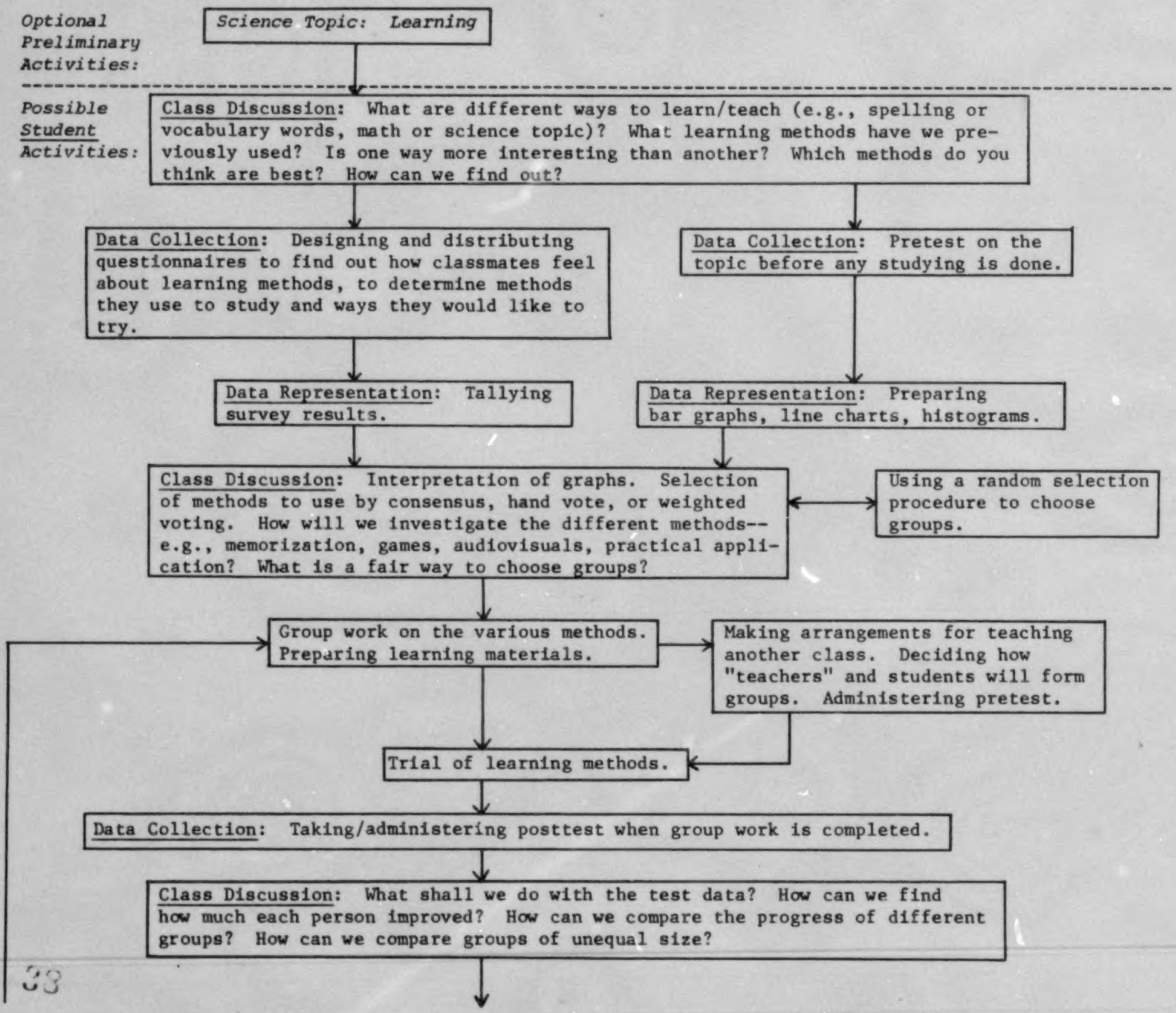
Primary children, of course, will not work at the same level as older students; however, they can propose experiments, collect and analyze data, and find a satisfactory solution to the problem. Aside from the specific topic studied, they also learn and practice, within a real context, skills and concepts in mathematics, language arts, science, and social science. While working on Ways to Learn/Teach, primary students improve their interpersonal relationships, develop problem-solving abilities, and realize that they can have a positive effect on the world in which they live.

4. FLOW CHART

The following flow chart presents some of the student activities--discussions, observations, calculations, constructions--that may occur during work on the Ways to Learn/Teach challenge. Because each class will choose its own approach to the challenge, the sequences of events given here represent only a few of the many possible variations. Furthermore, no one class is expected to undertake all the activities listed.

The flow chart is not a lesson plan and should not be used as one. Instead, it illustrates how comprehensive investigations evolve from the students' discussion of a Ways to Learn/Teach problem.

Challenge: Find the best way to learn or to teach someone else certain things.



Optional Preliminary Activities:

Science Topic: Learning

Possible Student Activities:

Class Discussion: What are different ways to learn/teach (e.g., spelling or vocabulary words, math or science topic)? What learning methods have we previously used? Is one way more interesting than another? Which methods do you think are best? How can we find out?

Data Collection: Designing and distributing questionnaires to find out how classmates feel about learning methods, to determine methods they use to study and ways they would like to try.

Data Collection: Pretest on the topic before any studying is done.

Data Representation: Tallying survey results.

Data Representation: Preparing bar graphs, line charts, histograms.

Class Discussion: Interpretation of graphs. Selection of methods to use by consensus, hand vote, or weighted voting. How will we investigate the different methods--e.g., memorization, games, audiovisuals, practical application? What is a fair way to choose groups?

Using a random selection procedure to choose groups.

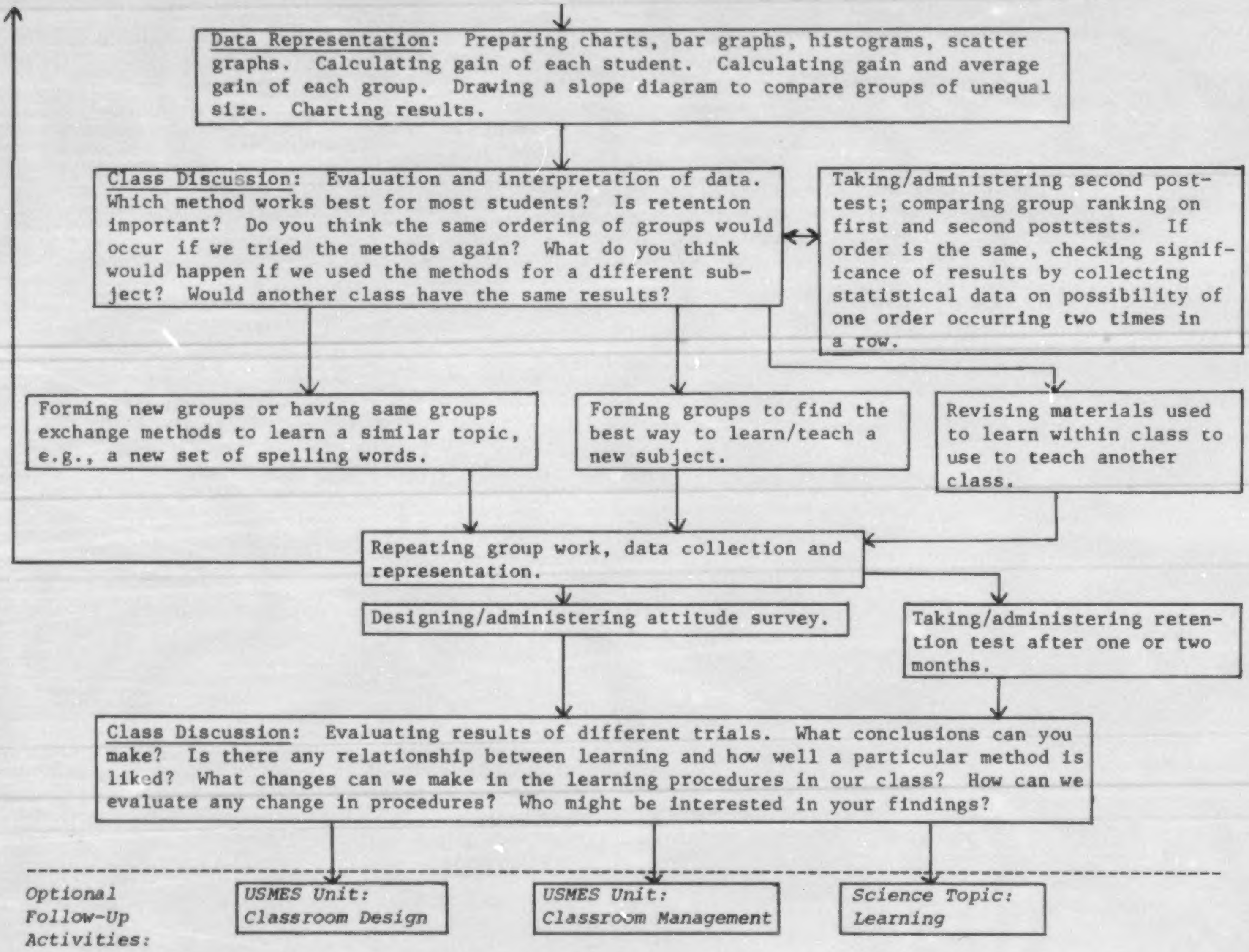
Group work on the various methods. Preparing learning materials.

Making arrangements for teaching another class. Deciding how "teachers" and students will form groups. Administering pretest.

Trial of learning methods.

Data Collection: Taking/administering posttest when group work is completed.

Class Discussion: What shall we do with the test data? How can we find how much each person improved? How can we compare the progress of different groups? How can we compare groups of unequal size?



Data Representation: Preparing charts, bar graphs, histograms, scatter graphs. Calculating gain of each student. Calculating gain and average gain of each group. Drawing a slope diagram to compare groups of unequal size. Charting results.

Class Discussion: Evaluation and interpretation of data. Which method works best for most students? Is retention important? Do you think the same ordering of groups would occur if we tried the methods again? What do you think would happen if we used the methods for a different subject? Would another class have the same results?

Taking/administering second posttest; comparing group ranking on first and second posttests. If order is the same, checking significance of results by collecting statistical data on possibility of one order occurring two times in a row.

Forming new groups or having same groups exchange methods to learn a similar topic, e.g., a new set of spelling words.

Forming groups to find the best way to learn/teach a new subject.

Revising materials used to learn within class to use to teach another class.

Repeating group work, data collection and representation.

Designing/administering attitude survey.

Taking/administering retention test after one or two months.

Class Discussion: Evaluating results of different trials. What conclusions can you make? Is there any relationship between learning and how well a particular method is liked? What changes can we make in the learning procedures in our class? How can we evaluate any change in procedures? Who might be interested in your findings?

Optional Follow-Up Activities:

USMES Unit: Classroom Design

USMES Unit: Classroom Management

Science Topic: Learning

5. A COMPOSITE LOG*

This hypothetical account of an intermediate-level class describes many of the activities and discussions mentioned in the flow charts. The composite log shows only one of the many progressions of events that might develop as a class investigates the Ways to Learn/Teach challenge. Documented events from actual classes are italicized and set apart from the text.

Following a class session during which the children began learning a new set of spelling words, the teacher asks, "Do you think we can find new and different ways to learn our spelling words which are better than the way we have been using?" The ensuing discussion becomes quite animated as the children talk about determining the best way to learn something new. One student remarks that book study and practice work best for him, while another mentions that having the teacher explain it helps her to learn. Other youngsters contribute their opinions, and the class decides to try several methods to learn their spelling words to find out which one is best.

One student asks, "Can we study math problems in some new ways?" A classmate adds that they might be able to find better ways to learn multiplication facts or fractions. However, others in the class point out that they had better stick to one topic at a time. By a hand vote they choose to study spelling words first and then try different ways to study math problems if they have time.

> *Class discussion of a new math subject, percentage, showed students in an eighth-grade class in Athens, Georgia, that the topic was new to all of them. They were challenged to find a method which they thought would be the best way to learn about percentage. (See log by Peggy Neal.)*

> *A teacher in Iowa City, Iowa, who was meeting with her fourth graders for the first time, began with a short get-acquainted game and then asked the students general questions about learning: "What new things have you learned this year? What new things have you found it hard to learn?...easy to learn? ...enjoyable to learn?" There was good response from the children, and at the second meeting the teacher asked whether they would like to try out some new methods to learn spelling words to find out if one way were better than another. The class accepted the challenge and held a brainstorming session of possible approaches to use in learning their weekly spelling words. (See log by Florence Duncan.)*

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*Written by USMES staff

During the next session the children review their discussion of ways they learn, and the teacher then asks whether they can think of some new ways they would like to try with their next list of spelling words. Several students have ideas, which the teacher then lists on the board:

1. Write each word once and spell it aloud.
2. Write each word three times and spell it aloud.
3. Test each other orally.
4. Write each word five times and misspelled words ten times.

The children are then asked to explain how the ways differ. After a lengthy discussion they conclude that the four ways are all variations of the same method--practice. The teacher asks them to think about ways they have learned other things. The children say they think they learned to ride bicycles by just doing it.

After several days of thought the children again discuss new ways to learn. Using words in sentences they write is brought up as another way to learn spelling words, but some students say that this is also a form of practice. The discussion then centers on different ways to practice spelling words, and the students list the following ways they might use:

1. Memorization--spelling each word silently or aloud without writing it.
2. Writing down each word several times without spelling it aloud; writing misspelled words several more times.
3. Games--spelling bee.
4. Reading the words in sentences and then writing each word in a sentence.

Fourth graders in New York City devised a list of their suggested ways to learn reading. To find out what other students thought about the methods, they conducted a survey of the sixth, seventh, and eighth graders and then added their new suggestions to the list. (From log by Peggy O'Brien.)

During an early evaluation of their Ways to Learn/ Teach activities, children in a sixth-grade class

> *in Boulder, Colorado, realized that all the methods used during their trials were variations of the practice method. In the session that followed, the students developed a list of ways to learn other than by repeated practice. The list included reading, observation, trial and error, explanation, experience, and games. (From 1974 log by Tom Dumler.)*

The students note that there may be other ways to learn the words, but these are the ways they wish to try. When the teacher asks how they will find out which way is best, one child suggests splitting up into four groups with each group trying a different method. After a short discussion of whether their grades on this set of spelling will be counted, the class agrees to form groups.

The next problem then is how to decide on group membership. Some students suggest that the teacher choose the groups so that all the "good" students won't be in one group. Others want to form groups according to their normal seating arrangement, but one girl points out that this may not be fair because friends sit together. "Let's have a lottery to choose the groups," says one of the boys. Several children don't believe that a random selection will result in groups that are fair, but they agree to try it.

> *The eighth-grade teacher in Athens suggested that groups be formed according to whichever method each child wanted to use. The students loudly objected; they felt the groups would not be equal in ability. They discussed using their class grades or the results of a pretest to select equal groups and finally asked the teacher to select the members for each group, subject to their approval. (See log by Peggy Neal.)*

> *In Ocala, Florida, sixth-grade students encountered a problem when they discovered that approximately two-thirds of the class wanted to work in the same group. They talked about different grouping methods and finally agreed to appoint as captains the five students with highest class averages. The teacher supplied the names and each captain selected a learning method and members for his/her group. (From log by Quinn Wiggins.)*

After considering various ways to make random selections, the class decides to put numbers in a bowl and have each child draw out a number which would range from one through four and would correspond to one of the ways to learn listed on the board. "How many of each number will we need?" asks the teacher. The children discuss this for a moment. As there are twenty-six students, there will have to be at least twenty-six slips, they decide. Dividing twenty-six by four, they find that seven slips for each number will be enough because that will provide twenty-eight slips for the drawing. Four children volunteer to make the slips for the next session.

The slips are prepared and put into a box. Everyone draws a number and the groups are formed, two with seven numbers and two with six. Some object to the group in which they have been placed because they want to use a different method. The class decides that the different groups will remain as they are for now but that they will change the method they use for the next set of spelling words.

> *After a lengthy discussion, seventh graders in Athens, Georgia, agreed to draw lots to determine group membership. Twenty-six slips of paper were prepared--equal to the number of students in the class--each containing one of the four group names. Each student then selected one slip from a box. A review of the results indicated that a second round was necessary--some students had ignored the draw and switched groups. The second round was more successful, and the group assignments were recorded. (See log by Ida Campbell.)*

The discussion now centers on how to measure the effects of each of the ways to learn. To provide a basis for judging the effectiveness of their different learning procedures, the children decide to take a pretest before beginning. Later, they will take a posttest and compare the results of the two tests.

The teacher then prepares a list of spelling words and gives the pretest. The children correct their papers and record everyone's score on a tally sheet, which the teacher keeps.

Eighth-graders in Athens decided which learning methods they would use to study percentage and then took a pretest. The teacher corrected the tests and recorded the scores for the children to use later when they took the posttest. (See log by Peggy Neal.)

Children in the seventh-grade Athens class, who were investigating the best way to learn geometry by teaching other students, spent six days, including one weekend, preparing materials for their three teaching sessions. They administered a test, designed by their teacher, at the beginning of the first teaching session and at the end of the third. (See log by Ida Campbell.)

The teacher of a fourth-grade class in Chicago, Illinois, asked her students how they would know that they had learned the spelling words during the week of their trial rather than before the experiment started. Two students simultaneously suggested that the class take a test before and after studying the words. (From log by Kathy Czagany.)

The next day the children begin studying the word list in their groups. The Memorization Group sits quietly as each member spells the words mentally. Then they go to the rear of the room so that they will not bother the other groups and begin spelling each word aloud five times; misspelled words are spelled aloud ten times.

The Writing Group practices writing each word at least five times. Words misspelled on the pretest are written ten times.

The Games Group at first wants to make flash cards with the word on one side and a picture for the word on the other. However, one member points out that many words, such as "when," don't have a corresponding picture. The group then decides to have a spelling bee and asks the teacher to read the words for them. When children misspell a word, they are out of the game, but they must stay and listen as the others continue. When only one student is left, he or she is declared the winner.

The Use Group reads a story containing the spelling words.

The sentences are passed around the group so that each child can both read and write several of the sentences containing new words.

After several days of group work the children take a posttest on the spelling words. They correct the papers, and the scores are recorded on the tally sheet and compared to the pretest scores to compute the gain for each person. The teacher asks whether anyone knows how to make a picture of the results, and one student suggests graphing each person's gain.

"But how are we going to tell which group did best?" one child asks. "There are more people in some groups than in others." A classmate suggests finding the average gain for each group and graphing that. The class agrees that this would be another, and perhaps better, way to represent the data. Because they are not quite sure how to calculate an average, they divide the USMES "How To" Cards. Several students who can divide go to the board, calculate the average gains, and draw a bar graph of the results.

Fourth graders in Iowa City used three learning methods to teach spelling words to third graders. Pretest and posttest scores were calculated by each group and then gains were displayed on charts and presented to the entire class. When the teacher asked how all the data from the three groups could be shown on one chart for easier comparison, several students used the overhead projector to explain their ideas. One chart was selected and then drawn on the board so that each student could make a copy. The teacher held a skill session on graphing, and the children transferred their data to line charts and bar graphs. (See log by Florence Duncan.)

Each group of the sixth graders in Boulder made a graph of their team's scores on the pretest. Various colors or dotted lines were used to differentiate each person's score. One student commented that it would be easier to determine the best improvement if all the information were represented on one graph, but a classmate objected, noting that such a graph would be extremely confusing and difficult to read. Another student suggested that the average score for each team be calculated and

> *graphed. This idea was accepted by the class and each team average was entered on the class graph. (From 1974 log by Tom Dumler.)*

Other children ask whether there might be another way to compare the groups without dividing to find the averages. The teacher explains that they can draw a slope diagram. The number of group members is plotted along the horizontal axis and the total points gained by the group along the vertical axis. Lines are then drawn from the origin to the plotted points. By comparing the steepness of the lines, the children can easily rank the group averages; the steeper the line, the higher the average.

With the help of the teacher and the USMES "How To" Cards, several students try their hand at slope diagrams (see Figure B5-1). They are happy to see that they achieve the same ranking as the students who calculated exact averages: the Writing Group had the best average, followed by Games, Memorization, and Use.

At the next session the class discusses the significance of the gains. Some children think the results show that some of the ways they used to learn the spelling words are better than others. Other children are not convinced. "Why couldn't it just happen that way?" one asks. They decide to repeat the entire process with a new list of spelling words.

After a pretest, a week of study, and a posttest, they again calculate and graph the average gain for each group. The groups finish in the same order as they had previously. By now, everyone is convinced that the results weren't simply pure chance.

To demonstrate this, the teacher puts four different-colored marbles in a box and asks a child to draw them out, one at a time, without looking. The order is recorded, and the teacher asks whether it is likely that the same order will be repeated if they try the experiment again. The class says, "No," and repeated drawings prove them correct: a different order results each time.

One child asks, "How many ways are there?" and the teacher suggests listing them on the board. The class works together to figure out the different orders in which the marbles can be drawn out. First, they list all the ways if the red marble is first. Next, they list all the ways with the green marble first, then with blue, and finally with yellow. When they are finished, they find there are twenty-four ways. Thus, they can see that the chances of the same order occurring twice are not very great. (Actually, the chance is 1/24 x 1/24 = 1/576.)

The reason for learning to spell new words is the topic of the next discussion. The children agree that it is important to know how to spell words so that they can write anything they want; therefore, remembering how to spell the words is important. To see whether any of their learning methods produces a better memory of the new words, the class decides that in a few weeks they will take retention tests on the first two groups of words they studied. Then they will see whether there is any reordering of the groups which would show that one method is best in terms of remembering how to spell.

> *Two months after completion of the Ways to Learn/Teach challenge, the eighth graders in Athens discussed their study of per cent. The class was asked how they thought they would do on a retest--whether the results for the four groups would be the same as on the posttest. The students thought the idea was interesting and agreed to take a test, similar to the posttest, to measure their retention of what they had learned about percentage. (See log by Peggy Neal.)*

Some students say that while they would like to continue with the spelling experiment, they would also like to try out different ways to learn math, specifically multiplication. The rest of the class and the teacher agree that now is a good time for the investigation. As suggestions are made for possible ways to learn multiplication, a student recorder makes a list on the board. Each item is discussed, and by consensus, the list is narrowed to the following five techniques:

1. studying the math book and practicing examples
2. games
3. audiovisual aids (prepared by the class)
4. teacher explanation as usual
5. practical application

Eighth graders in Athens suggested six ways to learn about percentage. Group discussions led to the selection of the following four methods:

1. *playing games*
2. *using learning centers*
3. *using tapes and films*
4. *business (practical application)*

(See log by Peggy Neal.)

After investigating different ways to learn geometry, seventh-grade students in the Athens class decided to apply the same methods to learn their next math topic--fractions. Two other mathematics classes acted as control groups and learned the material using a traditional approach--textbooks and instruction by the teacher. A pretest and a posttest were given to all three classes, and the results were used to compare the different learning approaches. (See log by Ida Campbell.)

Because their random selection of spelling groups had worked well, the children want to hold another drawing, this time with numbers from one through five. They also decide to use the chance selection to assign the methods to the groups. Numbers from one through five are placed in the box, and one child from each group draws a number which determines the method that group will use.

During the next session the teacher administers the pretest. The children correct their papers and record the scores.

The Games Group decides to try a game modeled after "Concentration." Cards are placed face down and the children take turns uncovering two cards at a time. Each time a child matches a pair, he/she gets a free turn. The person with the most pairs at the end of the game is the winner. (Sample pairs of cards are 4 x 8 and 32, 4 x 9 and 36, 5 x 8 and 40, etc.)

The Tapes and Filmstrips Group first watch a filmstrip on multiplication and discuss the new material. Each member of the group then makes up a problem and records it, along with an explanation of how to solve it, on a cassette tape. Afterwards, the entire group listens to the tape and works out each problem.

> *In the sixth-grade class in Athens, the Tape and Film Group spent one session using a cassette recorder and worksheet to learn about percentage. The concepts were explained slowly on the tape, and time was allowed for the children to complete the problems on an accompanying worksheet. In another session the group used a tape prepared by students in another math class. The tape instructed those listening to study a poster containing percentage equivalents in fractions and decimals. Examples of ways that equivalents would shorten the calculation time for percentages were explained, and answers to assigned problem sheets were also recorded. (See log by Peggy Neal.)*

The Practical Applications Group works with a catalog to place orders for multiple purchases of several items. They calculate the total for each item and then find the total cost of their order. Next, they use the price list from a nearby McDonald's and find the cost of multiple orders for hamburgers, cheeseburgers, french fries, etc.

> *In the sixth-grade class in Boulder, the Practical Application Group learned the metric system through the direct use of meter sticks. They measured items around the classroom including the chalkboard, flag, exit sign, room, themselves, and the teacher's desk. To avoid conflicting with another group's method, this group was asked not to use any books. (See log by Tom Dumler.)*

When all the groups have had sufficient time to complete their work, the teacher administers a posttest. The children correct their papers, record their scores, and calculate the average gain for each group. Bar graphs are drawn to depict the data, and the children discuss the results for the different methods.

At the next session the teacher gives a new multiplication pretest. The children again grade their papers and note that this test has fewer problems than the first one. The groups then begin studying the new problems using their designated methods.

At the end of the week the retention tests on spelling are given. When the papers are corrected and the scores recorded, the students find that while the Writing and Games Groups stayed the same, the Memorization and Usage Groups changed places. Possible reasons for the change are discussed, including the idea that perhaps one group didn't try as hard. They conclude that the first two methods are good ways to learn spelling words because these two groups were the top two each time.

The groups complete their work on the new multiplication problems and take the posttest. The students correct their papers, record the scores, compute the average gain for each group, and make a bar graph of the results. They immediately notice that the order of the groups has not changed. They conclude that the group which had the largest gain each time probably has found a better way for them to learn multiplication.

During the discussion of their results, the children raise the question of what to do next. They decide they want to continue their work on math and spelling, but with each group using another method. They feel that in this way each person can find out which method meets his/her own needs. Several students then suggest that they also experiment with primary children to find out which methods work best for them and whether there are differences in the best way to learn because of age level.

In a first-grade class composed of boys designated as slow learners, the teacher introduced a challenge to find the best way to learn math facts. From their list of possible approaches, the children chose three methods: worksheets, games, and manipulative objects. A five-minute pretest was given by the teacher, and the boys spent about a week working with whichever of the three methods they prepared. After a posttest, the teacher helped plot the gains on a number line. The investigation was repeated several times during the following weeks. Each time the boys were allowed to select any of the three methods. In final comparison, the children concluded that each person learned best when he used a method he really enjoyed. (From 1976 log by Anita Sabol.)

In the Boulder class the students decided they didn't want to learn another group of spelling words. Instead, they decided to try to use their methods to teach some of their schoolmates. This led to a discussion of their most successful method and why it was so successful. (From 1974 log by Tom Dumler.)

The seventh-grade Athens class changed the focus of their investigations of the best way to learn geometry from learning it by themselves to teaching it to others. The students asked the teacher to help them learn the topic by instructing them as usual. Afterwards they returned to their groups and used their assigned methods to teach other students about geometry. (See log by Ida Campbell.)

Children in the fourth-grade class in Iowa City, wanted to work with other children to determine the best way to learn spelling words. A third-grade teacher agreed to their request and scheduled a time for them to meet with her students. The class decided that each fourth-grader would give a pretest and prepare materials for two third-grade students. (See log by Florence Duncan.)

6. QUESTIONS TO STIMULATE FURTHER INVESTIGATION AND ANALYSIS

- Can we find a more interesting way to learn ______?
- Do people learn/teach things the same way?
- What way do you use to learn or teach someone something?
- Does it matter which way you use to learn/teach something?
- Is one way to learn better than another way? How can we find out?
- What information do you need to collect? How can you get it?

- How will we decide which learning methods to investigate?
- How can we find out what other children think about the ways they learn?
- How can you best organize yourselves to collect the data you need?
- How can we make a random selection of people for each group?
- What is a good way to keep a record of your data?
- How can you make a picture of your data?
- What does the data tell you?
- How can we test how much you remember?
- How can we find out if different ways are better for different people?
- How can we compare the results of the different tests if the total numbers of items on each test is different? Which test items show practical application more than the others?
- How can we compare group scores if the groups have different numbers of members?
- How can we tell whether the results of the groups show a significant difference or whether it was a matter of chance?
- What does the range of your data tell you?
- How could you find out if your method works best to learn/teach something else?
- How can we find out which is the most popular method? Is there any correlation between popularity and effectiveness of the methods?
- What conclusions can you make about your investigations? Who might be interested in your findings?

C. Documentation

1. LOG ON WAYS TO LEARN/TEACH

by Anita Sabol*
Vista View School, Grades 2-5
Burnsville, Minnesota
(April-May 1975)

ABSTRACT

Two science classes, containing students ranging in age from seven to ten years, worked cooperatively on the Ways to Learn/Teach challenge to find the best way to learn their next two areas of study--animals and inventors/inventions. Both classes used the same two methods--learning packets and research materials. Class A prepared lessons on animals for class B to use while class B prepared lessons on inventors/inventions for class A. During their two-month investigation, each class spent three forty-five-minute sessions per week developing and using learning materials, devising a pretest and a posttest, and finally compiling, graphing, and analyzing data.

During the last quarter of the semester, I asked students in two of my science classes whether they would like to find out the best way to learn our next two topics of study: (1) inventors and their inventions and (2) animals. When both classes responded enthusiastically, I proposed that each class devise lessons on one topic which would be used by the opposite class to learn the material. Thus, class A prepared lessons on animals for class B, and class B prepared lessons on inventors/inventions for class A.

We began our next USMES session with the children compiling the following list of ways they ordinarily used to learn something new:

1. observing
2. pictures and drawings
3. TV
4. experimenting
5. survey
6. writing
7. research
8. copying
9. asking questions
10. listening to teachers

Several children also prepared a short survey to determine which of these learning methods some of their schoolmates thought were best. The results showed that reading and research were the popular choices.

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*Edited by USMES staff

Planning the experiments involved much discussion. Students in class B had difficulty planning how to determine which group learned more. Their initial suggestions included--

1. give a test
2. have a survey
3. write reports
4. see how hard they tried

They decided, as did class A, that a pretest and a posttest would provide the most effective measure. One student noted that written tests make some children tense and thus are not an accurate measure of their knowledge. He suggested giving an oral test, and the class agreed that it could be done if some students requested it. Class B also discussed the values of learning in small groups versus large groups but they postponed any decision on grouping until the materials were prepared.

One issue concerned the form the pretest and the posttest should take. At first most students felt that a separate test should be given for each different topic within the subject area, for example, the cat family, inventions in the field of communications. One student suggested developing individual packets to use in evaluating progress, but some classmates objected; correcting and judging each child's work would be too difficult, they thought. After further deliberation the consensus was to use the same pretest and posttest for everyone in a class.

Children in class A had additional concerns over the amount of time allotted for learning the materials because several of them had to leave class for band. This problem was resolved by allowing those students to use equivalent amounts of their free time to make up the work.

Both classes spent the next several sessions in the media center locating materials in an attempt to narrow the scope of their subjects. One child preparing materials on inventors/inventions complained, "Almost everything is an invention!"

I met with each group at different times during these sessions to talk about their progress and their problems and to help them focus on their tasks. The children individually composed test questions on the two subjects and generally limited the scope to one or two particular animals or inventors/inventions.

Each class then compiled their questions on a master list, discussed each one, and selected the best ones to include on the tests. They established the following criteria for evaluating the questions:

1. Questions should be interesting.
2. Questions should be based on information most people wouldn't know.
3. Questions should be on information they, themselves, would like to know.
4. People should be able to find answers to the questions.

One full session was spent debating the pros and cons of different group formations. At first it involved only class A but quickly spread to class B as well. Students in class A had initially decided to group class B students according to their pretest scores, but this decision did not please everyone. Some students were adamant that easier work should be given to younger class members. Others suggested having students in class B choose partners to teach, but this idea was rejected for fear that copying would result. Still another opinion was to choose group leaders in class B who could encourage their group members to work and then report on the progress of each group. This, too, was refused when one child pointed out that group leaders would have less time to do their own work.

Decisions on group formation and methods of teaching/learning were made at the following session. Children in class A finally agreed to select group members randomly. After examining their pretest questions, they chose to make the following types of learning materials for the other class to use: (1) reference materials, (2) learning packets, (3) tapes, and (4) books. Children in class B decided on two methods for class A to use--(1) learning packets, and (2) reference materials. Their groups were chosen by drawing names from a box and allowing each child to choose a group.

Both classes extended the number of days for preparing materials from four to six and shortened the time for teaching the other class. During the preparation sessions many teaching groups had difficulty organizing themselves, but all managed to get their work done. One girl spent five hours looking up the answers to her class's pretest and preparing directions for the other class to use.

In class A the group working on the book method had trouble locating answers to their questions because many of their

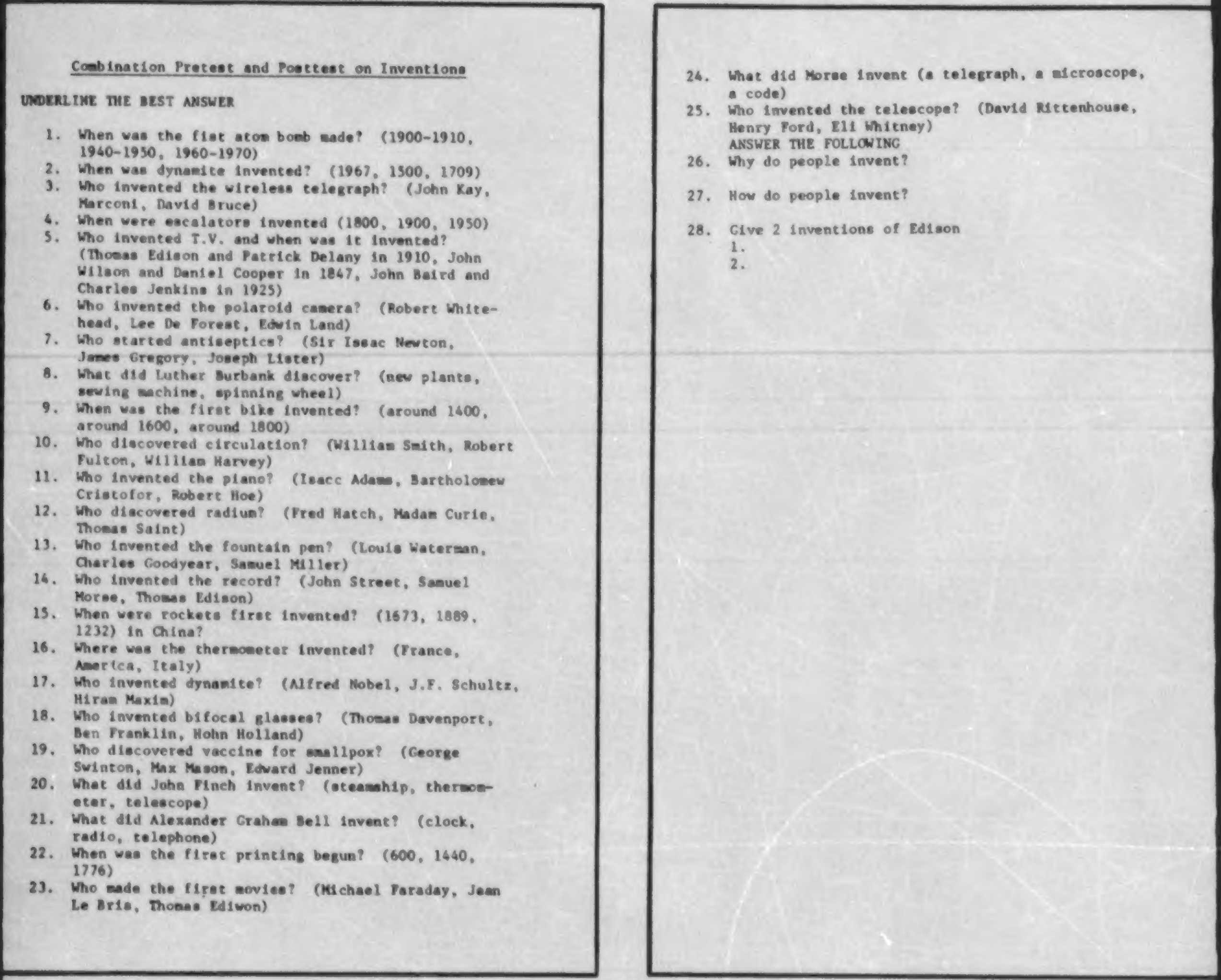
Combination Pretest and Posttest on Animals

FIND THE BEST ANSWER. UNDERLINE IT.

1. What is the most famous member of the cat family? (lion, tiger, bobcat)
2. How long before kittens open up their eyes? (about 2 days, about 10 days, about one week)
3. How large can dogs grow? (6 feet, 10 feet, 4 feet)
4. How large can house mice grow? (2½-3½ inches, 5-6 inches, 1½ inches)
5. How many monkeys usually travel together in a group? (25-30, 200-300, 100-200)
6. Why do people cover bird cages at night? (it's more comfortable, birds like it, so birds won't make noise)
7. Three dangerous snakes in the United States are: (boa constrictor, king python, cobra) (coral, rattlesnake, bull) (water moccasin, copperhead, diamond back)
8. What is a reptile? (warm blooded animal, cold blooded animal, always slimy)
9. How long can horses live? (10 years, 13 years, 17 years)
10. What is the most common pet snake in the United States? (bull snake, garter snake, rattlesnake without rattles)
11. How much do most horses weigh? (300-1,000, 1,000-2,000, 2,000-3,000)
12. Where would you find rabbits homes? (in caves, in bushes and woods, near streams)
13. How long do cats live? (8-15 years, not longer than 7 years, 20-25 years)
14. What are 2 living dinosaurs? (turtle and crocodile, blue whale and elephant, shark and crocodile)
15. How many kinds of monkeys exist? (300, 500, two main kinds)
16. Why do cats sit near doorways without ever being trained to sit there? (they enjoy that part of the house, to go to the bathroom, they like doorways)
17. What kind of cat doesn't have a tail? (Calico, Persian, Manx)
18. What is a DoDo bird? (a bird the size of a turkey, a bird the size of a robin, a very mean bird)
20. Why are DoDo bird's extinct? (they died of a disease, they couldn't find enough food, People liked to eat them)
21. Why do animals grow? (they want to, in order to live and take care of themselves, it is easier to do things that way)
22. What is the fastest kind of horse? (Palomino, Mustang, Arabian)
23. What is the longest snake in the world? (boa constrictor, bull, anaconda)
24. Why do skunks have a smell. (they goet it after they were born, they like it, for protection)
25. Why do some animals have shells and others don't. (because the air hurts them, for special protection, because they get sick without shells)
26. How do camels live in the desert? (they are born in the desert, they prefer the desert, they store food and water in their stomach and humps)
27. How many kittens are in a litter? (around 13, usually 5 or 6, usually 9 or 10)
28. A dolphin is a (fish, reptile, mammal, insect).
29. How longs do monkey's live? (5 years, 20 years, 11 years)
30. ANSWER THIS QUESTION
    Give three ways in which snakes are useful.
    1.
    2.
    3.

Figure C1-1

This test has been typed verbatim from the children's copy.



Combination Pretest and Posttest on Inventions

UNDERLINE THE BEST ANSWER

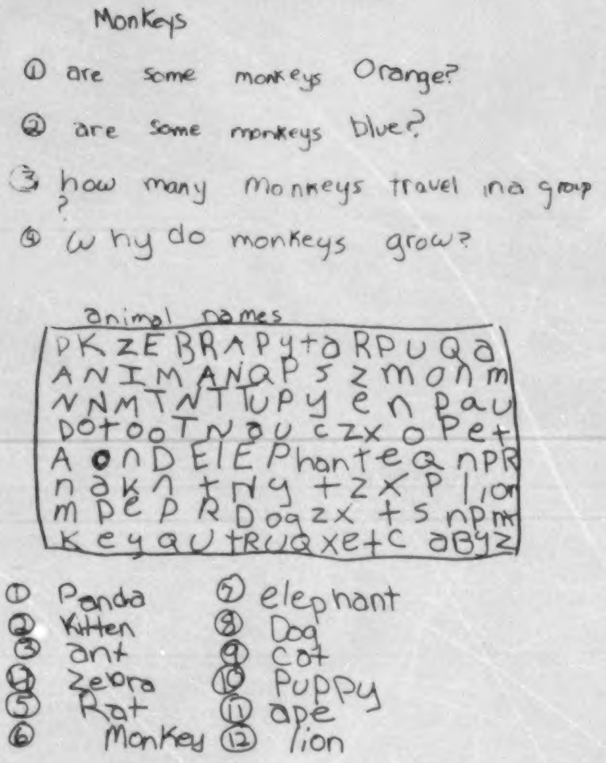
1. When was the fist atom bomb made? (1900-1910, 1940-1950, 1960-1970)
2. When was dynamite invented? (1967, 1500, 1709)
3. Who invented the wireless telegraph? (John Kay, Marconi, David Bruce)
4. When were escalators invented (1800, 1900, 1950)
5. Who invented T.V. and when was it invented? (Thomas Edison and Patrick Delany in 1910, John Wilson and Daniel Cooper in 1847, John Baird and Charles Jenkins in 1925)
6. Who invented the polaroid camera? (Robert Whitehead, Lee De Forest, Edwin Land)
7. Who started antiseptics? (Sir Issac Newton, James Gregory, Joseph Lister)
8. What did Luther Burbank discover? (new plants, sewing machine, spinning wheel)
9. When was the first bike invented? (around 1400, around 1600, around 1800)
10. Who discovered circulation? (William Smith, Robert Fulton, William Harvey)
11. Who invented the piano? (Isacc Adams, Bartholomew Cristofor, Robert Hoe)
12. Who discovered radium? (Fred Hatch, Madam Curie, Thomas Saint)
13. Who invented the fountain pen? (Louis Waterman, Charles Goodyear, Samuel Miller)
14. Who invented the record? (John Street, Samuel Morse, Thomas Edison)
15. When were rockets first invented? (1673, 1889, 1232) in China?
16. Where was the thermometer invented? (France, America, Italy)
17. Who invented dynamite? (Alfred Nobel, J.F. Schultz, Hiram Maxim)
18. Who invented bifocal glasses? (Thomas Davenport, Ben Franklin, Hohn Holland)
19. Who discovered vaccine for smallpox? (George Swinton, Max Mason, Edward Jenner)
20. What did John Finch invent? (steamship, thermometer, telescope)
21. What did Alexander Graham Bell invent? (clock, radio, telephone)
22. When was the first printing begun? (600, 1440, 1776)
23. Who made the first movies? (Michael Faraday, Jean Le Bris, Thomas Ediwon)
24. What did Morse invent (a telegraph, a microscope, a code)
25. Who invented the telescope? (David Rittenhouse, Henry Ford, Eli Whitney)

ANSWER THE FOLLOWING

26. Why do people invent?
27. How do people invent?
28. Give 2 inventions of Edison
    1.
    2.

Figure C1-2

This test has been typed verbatim from the children's copy.



Monkeys

① are some monkeys Orange?

② are some monkeys blue?

③ how many Monkeys travel ina grop ?

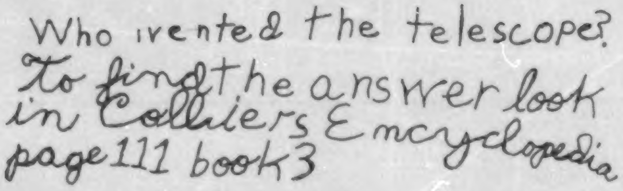
④ why do monkeys grow?

animal names

PKZEBRAPytaRPUQa
ANIMANaPszmonm
NNMTNTTUPyenpau
DOtooTNauczxoPet
AonDElEPhanteanPR
nakntNytzxPlion
mpePRDogzxtsnpm
KeyaUtRUaxetcaBYZ

① Panda
② Kitten
③ ant
④ Zebra
⑤ Rat
⑥ Monkey
⑦ elephant
⑧ Dog
⑨ Cat
⑩ Puppy
⑪ ape
⑫ lion

Figure C1-3



Who irented the telescope? To find the answer look in Colliers Encyclopedia page 111 book 3

Figure C1-4

ideas for questions had originally come from the encyclopedia. To ease their problem, they obtained permission from the Reference Materials Group to encroach on their territory by using a series of animal books set up in the reference room.

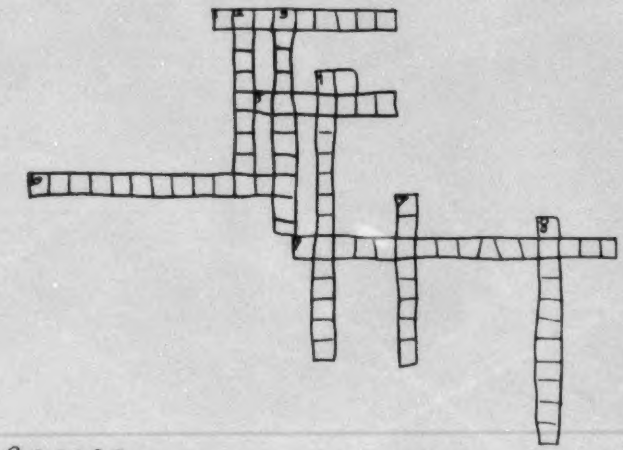
Several sessions later students in class A met to examine their efforts. Both the Tape Group and Book Group were having considerable difficulty preparing materials. By a majority vote the class decided to merge these groups; thus, tapes and learning packets became one group and books and reference materials the second group.

Children in both classes duplicated their own materials and were fascinated by the process. To save paper, I encouraged them to share duplicating masters so they could duplicate complete pages. Generally there was an atmosphere of support among children in both classes. As one group completed work, members joined another group to aid them. I was delighted with the response of the younger children, especially the second graders who used many reference books, including *The Guinness Book of World Records* and the *Lincoln Library*. Only a few students in each class did not actively participate.

I called the classes together to talk about the tests they had prepared. Because their questions were open-ended, I suggested adding several answers to each question to make multiple choice tests, which would make data handling easier. The children agreed that it would also be easier to choose from predetermined information than to come up with the answers from their heads. Copies of their combination pretests and postests are shown in Figures C1-1 and C1-2.

Early the next week, the children were divided according to age and then had their names drawn so that they could select groups in which to work. Both classes had decided earlier that each group preparing a packet of materials would include children at all age levels and that each group studying a packet would be of the same age. After this was completed and the pretests were administered (in some cases the questions were read aloud for those who had difficulty reading them, the children spent five sessions working in their groups with the prepared materials. (Samples of materials prepared by different groups can be seen in Figures C1-3, C1-4, and C1-5.)

Complaints from both classes centered on the lack of organization and difficulty in reading the writing in some of the materials. One child said he felt it was impossible to answer some of the questions.



across

1. what did John Finch invent?
5 how does man invent?
6 who discovered vacine?
9 who invented the telescope?
4 (abbrebiate) Benjam Franklin

DOWN

2 what did Alexander GramBell discover?
3 who invented dynamite?
4. who invented the stove?
7 what did the wright brothers invent?
8 who made the first movies?

Figure C1-5

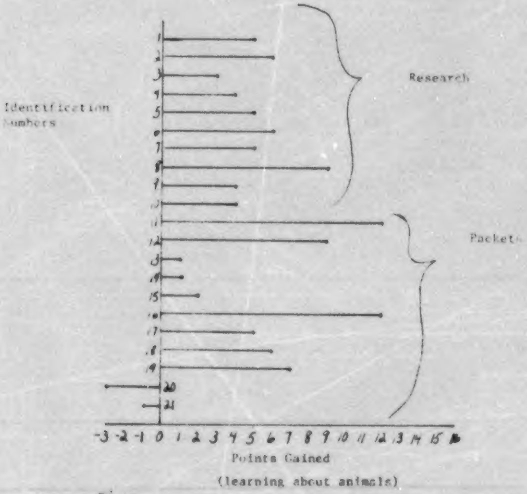


Figure C1-6

Later both classes spent an hour and a half discussing the results of their learning/teaching experiment, scoring the tests, and organizing the data.* Because of scheduling conflicts, the classes met separately.

Meeting with the children in class B, I asked how we could show on the board which method of learning was better --both classes had used the same two methods, learning packets and reference materials. Approximately half the students were familiar with graphs, and many children had suggestions. One idea was to place the number assigned to each child, instead of the name, along the vertical axis and the number of points each child received along the horizontal axis. As all scores had been determined on the basis of incorrect answers, it took additional calculations to determine the number of correct answers each child had. The class decided to plot both the pretest and the posttest score for each child in different colors.

Members of the Research Group finished their graph, but those in the learning Packet Group complained that the method was too time consuming. I challenged them to think of an easier way to graph the data. Several children suggested finding the difference between the pretest and posttest scores and adding up the totals for each group. My sketch of the graph that was made on the board as a result of this discussion is shown in Figure C1-6.

After completing the graphs, the children added the total points gained for each method. I then explained averaging, and together we averaged the scores for the topic of animals: research--5, learning packets--4½. One child announced he didn't understand why the Packet Group did not have a higher average score because it contained two 12s and one 9. A classmate pointed out that the group also had some minus points and that many children had low scores which accounted for the low group average. Several students were surprised that some children had very few wrong answers on the pretest and only a few more right on the posttest although they had worked quite hard; on the other hand, others got up to twenty wrong on the pretest and gained many points on the posttest.

The children in class B decided that there had not been much difference in using either method but felt that their learning would improve if they were allowed to choose the

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*Test scores were not made available.--ED.

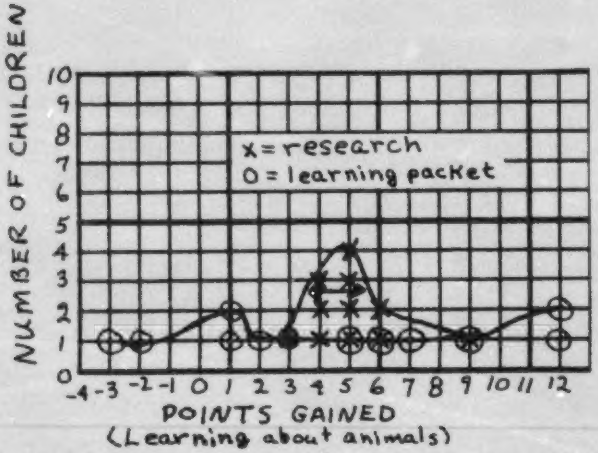

Figure C1-7

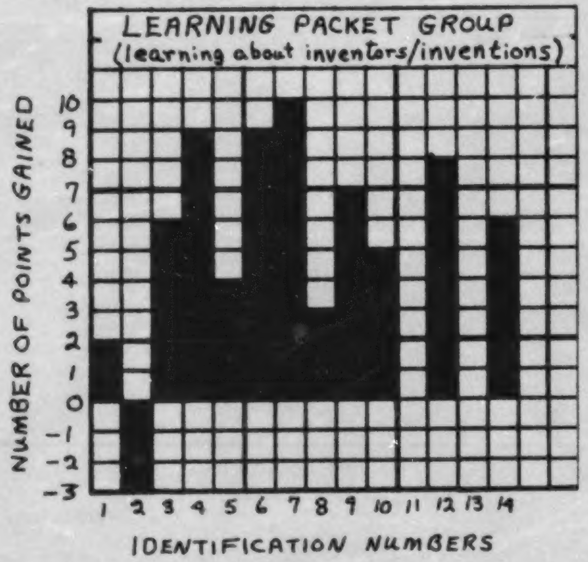

Figure C1-8

method they liked best.* Some students stated that packets were more fun but that several questions had been "dumb" and difficult to read. Students in the Research Group had similar comments and an additional complaint of incorrect listings of pages to read. They noted that there was an advantage to the research method in that many interesting bits of information were learned while looking up the specific facts. I asked the class to think about whether they had learned more as facilitators preparing materials on inventors/inventions, as learners studying about animals, or the same for both. At first a show of hands produced the following results:

As Teachers	The Same	As Learners
6	15	0

I then asked whether the children preferred to make their own decisions about learning or have a teacher direct them. A show of hands produced the following breakdown:

Children Directing and Deciding	Teacher In Charge	Not Sure
12	7	2

As teachers and facilitators they said they learned that a teacher—

1. must look up a lot of information
2. must be accurate about what is written down
3. might have trouble with the "ditto" machine
4. must be careful not to write too small, too close, too light, or too dark

Several children admitted that their group had "goofed up" some of the papers they prepared for the other class.

On the following day, I met with students in class A. We began by discussing the second graph that class B had made. We noted how close the scores were, and the children agreed with class B that both ways seemed about equally good. I then showed them a distribution graph of the scores of

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*The children might design a survey that would indicate whether the other class felt that a method was fun, slightly interesting, or boring.--ED.

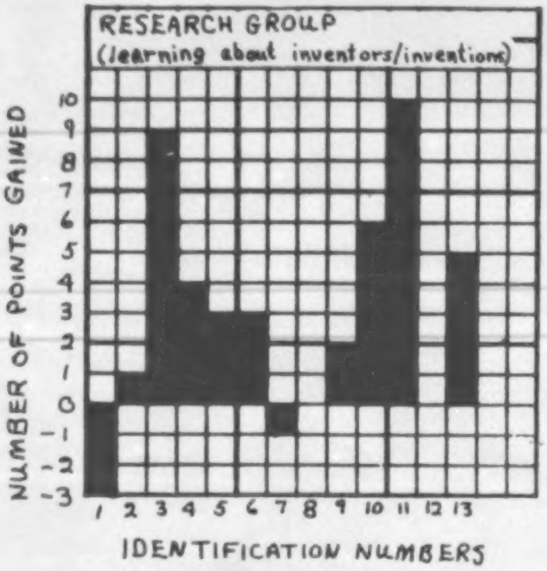
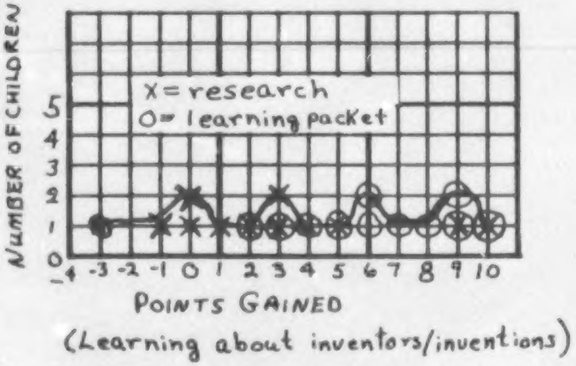


Figure C1-9



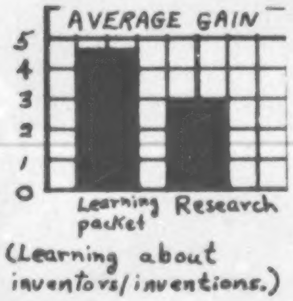


Figure C1-10

class B (see Figure C1-7). After examining the graph, the children concluded that because more students were in the middle for research, perhaps research was the better method for learning about animals.

Many children in class A needed additional time to take the posttest and have it scored by a classmate. While this was being done, the other students began to work on graphing skill sheets. Then with all the test results compiled, the children decided to draw on the board a bar graph for each group showing points gained from pretest to posttest. (See facisimilies reproduced in Figures C1-8 and C1-9.)

When the graphs had been completed, the children added the points and divided by the number of students in each group to come up with the average number of points gained--4.7 for learning packets and 3 for research. Not content to stop at this point, they also decided to make a distribution graph and another bar graph.* (See facsimilies reproduced in Figure C1-10.)

We then calculated how much of the positive end we would have to take off in order to make up for the negative scores. Next, we divided the graphs in the center and came close to the averages of 4½ points and 3 points.

With only a few minutes left, I asked the children to vote on the same two issues that class B had voted on. The results are shown below.

As Teachers	The Same	As Learners
4	6	15
Children Directing and Deciding	**Teacher In Charge**	**Not Sure**
13	0	12

I found our greatest limitation to be lack of time. Yet, despite the scheduling difficulties and quickened pace as school drew to a close, the children remained enthusiastic and motivated throughout their investigations.

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*The two classes might compare the results on the two topics and discuss whether one method might be better for one topic and another method better for another topic.--ED.

2. LOG ON WAYS TO LEARN/TEACH

by Florence Duncan*
Ernest Horn School, Grade 4
Iowa City, Iowa
(April-May 1975)

ABSTRACT

This class of fourth-grade students met two or three times per week to apply the Ways to Learn/Teach challenge to their study of spelling words. They began by designing and constructing teaching "machines." After several sessions the focus of their investigations changed to teaching spelling words to a third-grade class. The fourth graders divided into three groups--Teaching, Practice, and Games--and prepared appropriate materials which they used to teach the words to the younger children. Pretests and posttests were administered and the data were tallied, organized, and displayed on charts and graphs. An analysis of the results showed that the practice method had been most effective.

In April, when I met a new group of fourth graders for the first time, we began our meeting with a short get-acquainted game. I followed the game with a discussion of learning, asking such general questions as, "What new things have you learned this year?" "What new things have you found it hard to learn?...easy to learn?...enjoyable to learn?" There was a good response to these questions from everyone and a lively discussion ensued of what things made learning interesting, easy, difficult, or boring.

During the next session we reviewed our discussion. Then I asked the children whether they would be interested in trying out some of their suggested methods to learn spelling words and to determine whether one way was better than another. The class developed a list of ways to learn spelling which I recorded on the board as follows:

1. words flashed on a screen
2. write the word ___ times
3. read and study
4. make sentences using words
5. write definitions
6. posters
7. write a story
8. practice test
9. crossword puzzle
10. spelling bee
11. spelling tape
12. slide projector

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Three items--write definitions, write a story, and crossword puzzle--were challenged by the children as being really helpful in learning to spell words.

We began our next session by discussing the advantages and disadvantages of the various methods of learning spelling words. The children unanimously decided on a pretest and posttest to help them determine the best method and I chose the following ten words from a list designated as the 500 most misspelled words:

1. escape
2. luxuries
3. mosquitoes
4. neighbor
5. occurrence
6. paralyze
7. concern
8. stubborn
9. across
10. discuss

Everyone agreed that this would be a good spelling list to use!

During the next several sessions the children focused on learning to spell the words by using various teaching aids. Before they began their work, I gave them an oral pretest. Their designs of teaching aids included different types of spelling boxes with paper threaded through them on which the words were written. One child expressed concern that they needed to know their words in order to make spelling machines. Others in the class disagreed, stating that this would give such projects an advantage in learning the words. After much discussion and questioning over a period of several class sessions, I asked the children whether they would be more interested in trying to teach the spelling words to other students; they responded enthusiastically.

To begin our new challenge--to teach the ten spelling words to others--we had to reorganize our earlier list of ways to learn spelling to eliminate overlap. We narrowed the twelve ways to three--practice, teaching, and games. One student volunteered to ask two other teachers if we could enlist their classes in the experiment. The second/third-grade teacher whom they asked agreed to let my class visit her students the next day to explain the project and administer the pretest.

The rest of the day was spent in forming the three different groups and in planning activities to use in the experiment. At the end of the session the children met as a class to hear reports from each group. Members of the Game Group reported that each child would make a different game to use with the third graders. The Practice Group decided on several different practice activities: (1) write the word forty times, (2) write a sentence containing the word ten times, (3) use a prepared spelling tape, and (4) say the word and spell it twenty-five times. Children in the Teaching Group reported that they were going to have a spelling bee, a very popular small group activity in our intermediate spelling classes. In addition, they agreed to use flash cards to teach the children the words.

A quick planning session was held before going to the primary unit the next day. Two students volunteered to explain the project to the second and third graders, and I asked how they planned to take care of the differences in class size. After a head count showed that there were twenty-four primary children and twelve of us, my students agreed that each fourth grader would test and prepare materials for two students.*

The explanation and pretest went smoothly, and we returned to our classroom where we checked and discussed the pretests. The class decided that each of the three groups would chart its own scores. I asked the students how they could keep from hurting the feelings of the second and third graders who had missed many words. They suggested using numbers rather than names.

Before the session ended we agreed to devote two class sessions to the preparation of materials. Those students who completed their preparations early helped others to finish. One of my students, who was just learning to speak English, also participated in the experiment. He was aided by classmates who helped him learn to pronounce and spell the words correctly.

On the predetermined day my students went to the primary classroom, and each joined the two students he/she had pretested. They immediately began working on the spelling words using the methods they had prepared. Although a few groups sat around desks, most sat on the floor. Their concentration appeared intense and their behavior was excellent. One third grader challenged our spelling of one word because he had looked it up in an unabridged dictionary and found it spelled differently. We stopped to check the dictionary and discovered that both spellings were listed—mosquitos and mosquitoes.

My students returned to the primary room on another day to administer the posttest. Several primary students had to

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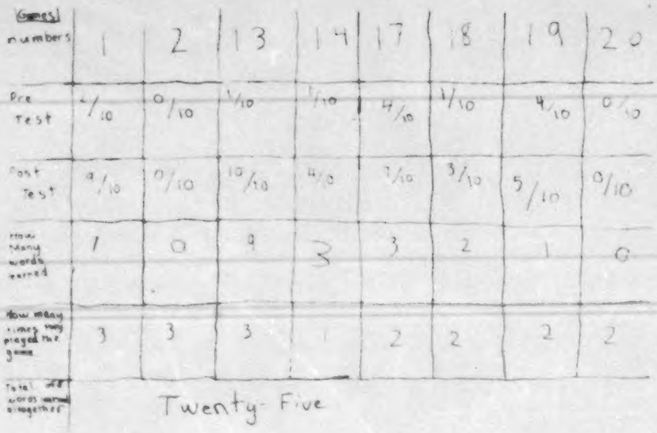
*The children might discuss how the second and third graders should be distributed among the different groups.--ED.



Games numbers	1	2	13	14	17	18	19	20
Pre Test	[illegible]/10	0/10	1/10	1/10	4/10	1/10	4/10	0/10
Post Test	9/10	0/10	10/10	4/10	7/10	3/10	5/10	0/10
How Many words learned	1	0	9	3	3	2	1	0
How many times they played the game	3	3	3	1	2	2	2	2
Total words learned altogether	Twenty-Five							

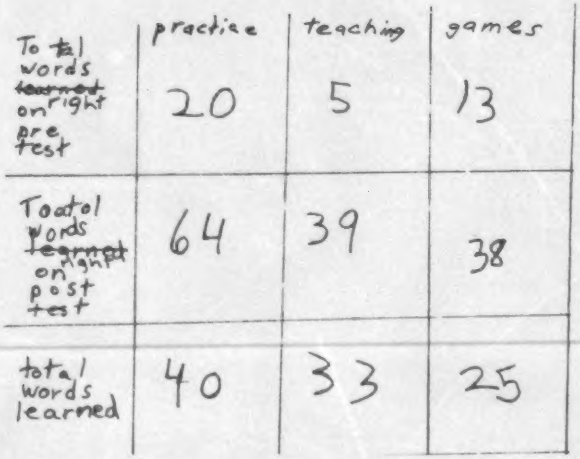
Figure C2-1

have their posttests scheduled for another time because they were out of the building.

When the data were collected, we spent three class sessions analyzing it. Each group prepared a chart of their data, which they brought to a full class discussion. (See Games chart in Figure C2-1.) A spokesperson for each group presented the chart to the class and led a discussion of the data.

When the reports were completed, I asked the children to devise one chart to show the totals of all three groups so that we could easily compare them. I set up the overhead projector, and several students came up and proposed charts, drawing them as they talked. The class was actively involved in making suggestions and asking questions. The final chart was written on the board, and each student made his/her own copy. (An example of their charts can be seen in Figure C2-2.*)

I held a skill session on graphing, and then the students prepared line charts and bar graphs of the total pretest and posttest scores as well as the gain for each group (see Figures C2-3, C2-4, and C2-5). The graphs clearly showed that the children who had learned the spelling words through practice made the greatest gains.**



	practice	teaching	games
Total words ~~learned~~ on right pre test	20	5	13
Toatol words ~~learned~~ on right post test	64	39	38
total words learned	40	33	25

Figure C2-2

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*The students might discuss how a difference in the size of the groups would affect their analysis of the results. To compensate for this difference, the students might find the average gain for each group and compare these averages. If students have trouble dividing, slope diagrams can be constructed to show the comparison of the ratios of total scores to number of people in the groups.--ED.

**The students might find out whether the second and third graders liked learning spelling words in the way they were taught. A simple survey could be designed to find out whether the students were very interested, somewhat interested, or bored.--ED.

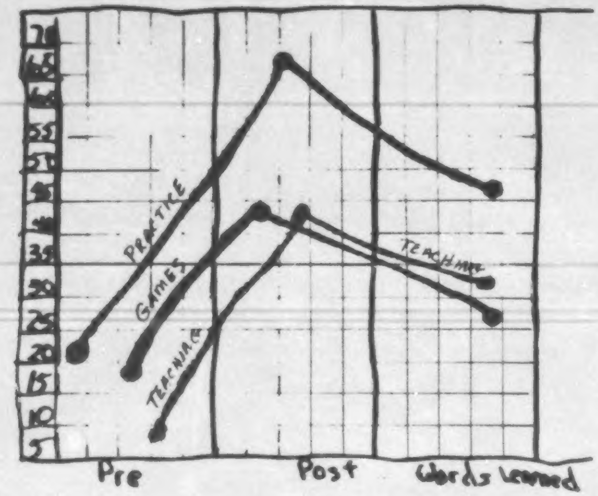

Figure C2-3

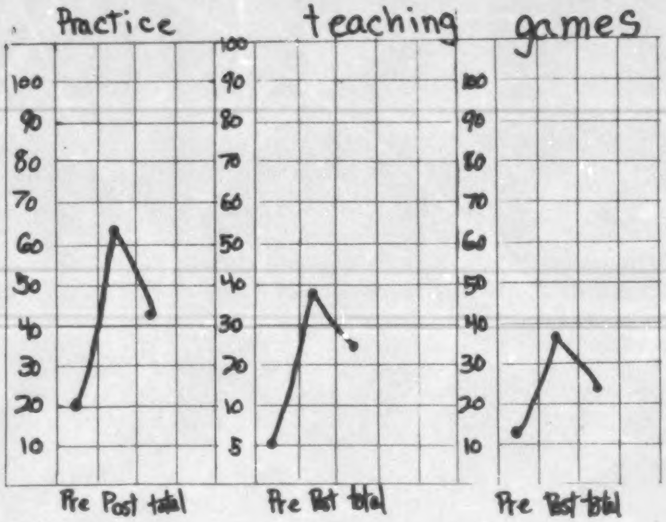

Figure C2-4

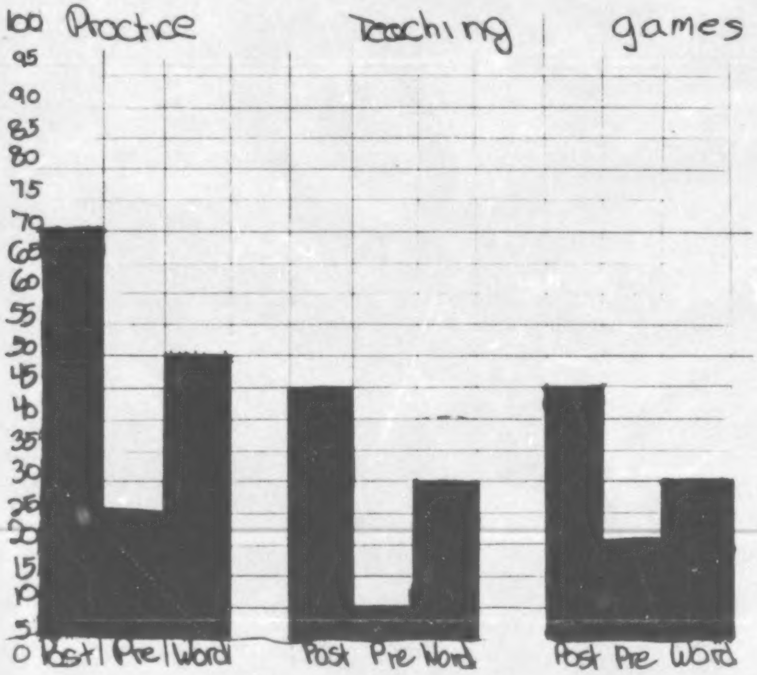

Figure C2-5

3. LOG ON WAYS TO LEARN/TEACH

by Thomas Dumler*
Heatherwood School, Grade 6
Boulder, Colorado
(April-June 1973)

ABSTRACT

In this sixth-grade class the Ways to Learn/Teach challenge was applied by the children to their study of the metric system. The class agreed to take a pretest and a posttest to facilitate evaluation of their investigations of four methods: (1) memorization, (2) reading and research, (3) teacher-taught, and (4) practical application. Students discussed the importance of group selection and formed groups on the basis of their preference for a given learning method. After several weeks of group work, the posttest was taken. Papers were scored, averages were calculated, and comparisons of pretest and posttest results were made. The children converted the raw scores to percentages and computed gains and losses. They discussed their findings and cited possible reasons that some groups had performed better than others.

After a discussion of the ways in which learning could occur, my sixth-grade class accepted my challenge to find the best way to learn their next math topic--the metric system. The class had already taken a pretest on the metric system, and the students agreed to take a posttest test after their investigations were completed to facilitate a "before and after" evaluation.

During the next session the class decided to work in four groups, each investigating a different method of learning: (1) memorization, (2) reading and research, (3) teacher-taught, and (4) practical application. To insure good results, the class decided that the membership of each group should be as even as possible. As there were twenty-four students in the class, they determined that each group would have six members. Children were assigned to groups according to their preferences which were expressed by a ballot vote.**

The group of students working on the research and reading

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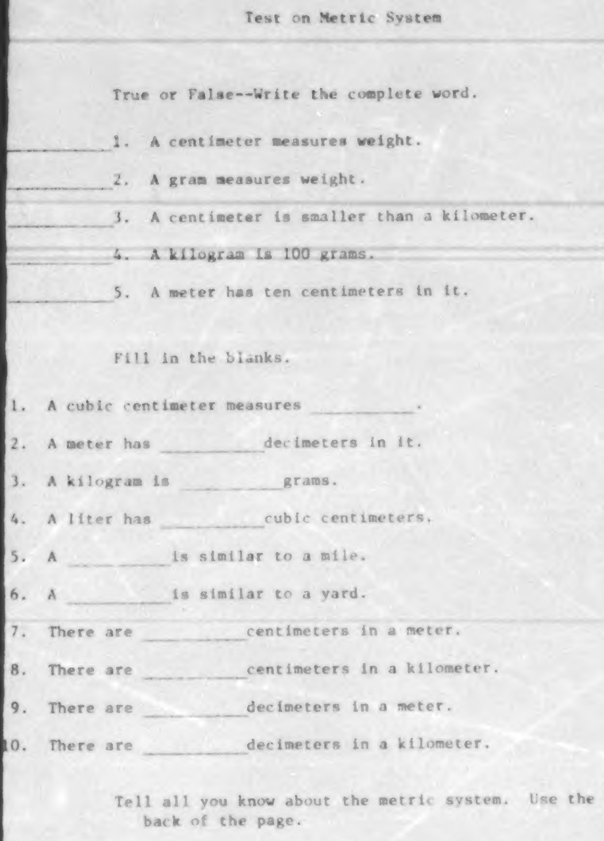
**Groups might be formed by random selection or by using the results of the pretest. Otherwise, one group may be composed of children who learn faster than others.—ED.



Test on Metric System

True or False--Write the complete word.

__________1. A centimeter measures weight.

__________2. A gram measures weight.

__________3. A centimeter is smaller than a kilometer.

__________4. A kilogram is 100 grams.

__________5. A meter has ten centimeters in it.

Fill in the blanks.

1. A cubic centimeter measures __________.
2. A meter has __________decimeters in it.
3. A kilogram is __________grams.
4. A liter has __________cubic centimeters.
5. A __________is similar to a mile.
6. A __________is similar to a yard.
7. There are __________centimeters in a meter.
8. There are __________centimeters in a kilometer.
9. There are __________decimeters in a meter.
10. There are __________decimeters in a kilometer.

Tell all you know about the metric system. Use the back of the page.

Figure C3-1

method began by brainstorming topics to research and listing possible references. Sources included the encyclopedia (*World Book*), books listed in the card catalog in the library, and film strips. During their research, they were asked not to do any problems or use meter sticks because this would conflict with another group's method.

The Practical Application Group was to learn the metric system through the direct use of meter sticks. They compiled a list of things to measure in the room including the chalkboard, flag, exit sign, room dimensions, themselves, and my desk. This group was asked not to use any books.

Children in the Memorization Group were instructed to use only mathematics books for their study. They looked up a metric table in one of their books; one child began to read the quite lengthy chart aloud and was met with groans from his classmates. I suggested that the group consider using flash cards to aid them in their task.*

The six students in the Teacher-Taught Group were going to be taught the metric system by me according to information in our math book. They began by defining a list of terms which included decimeter, kilometer, liter, and gram. They were then asked to define centimeter and to determine the number of centimeters in a meter.

Group work continued for several weeks. Students in the Practical Application Group measured objects both in the classroom and around the school. First, they measured the items in feet and then converted their measurements to the metric system. Group members established the procedure of estimating before measuring. Then, once the measurements were taken, the actual measurements were compared with the estimates for accuracy.

The Teacher-Taught Group worked on problems from a math book. They were encouraged to consult with each other whenever they ran into difficulty. I also spent several sessions with them discussing the metric system in terms of our money system. The Reading and Research Group divided; some students worked in the library, while others chose to remain in the room to copy conversion charts from the encyclopedia. The Memorization Group developed and used flash cards such as "a centiliter = ? of a liter." The questions were on one side, and the answers were on the reverse side. Several members also prepared equivalence charts to be used by the group.

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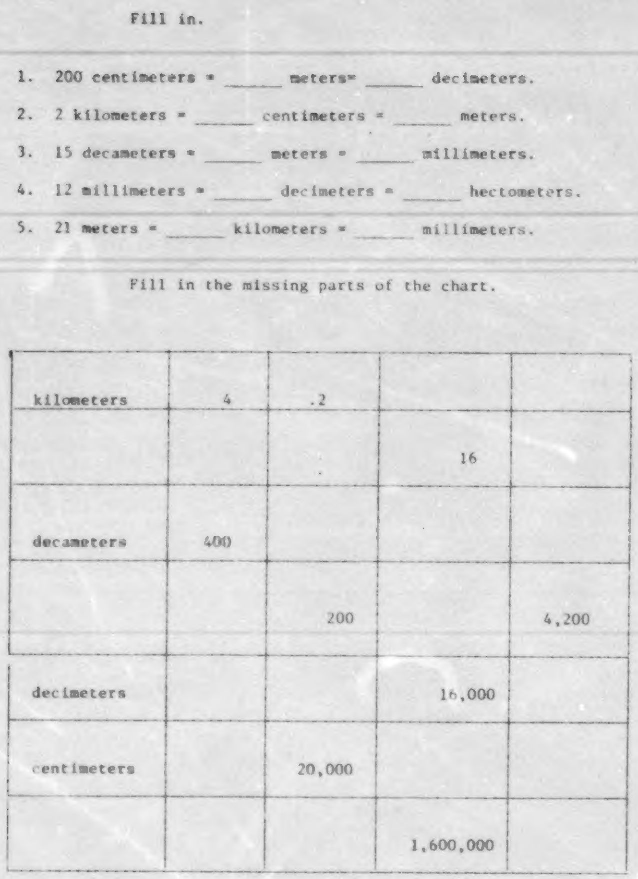
*The students might be asked to suggest ways to facilitate memorization.—ED.



Fill in.

1. 200 centimeters = ______ meters= ______ decimeters.
2. 2 kilometers = ______ centimeters = ______ meters.
3. 15 decameters = ______ meters = ______ millimeters.
4. 12 millimeters = ______ decimeters = ______ hectometers.
5. 21 meters = ______ kilometers = ______ millimeters.

Fill in the missing parts of the chart.

kilometers	4	.2		
			16	
decameters	400			
		200		4,200
decimeters			16,000	
centimeters		20,000		
			1,600,000	

Figure C3-2

The posttest was given to the class in early June. Each section was carefully explained, and everyone had an equal amount of time to complete the test. (A copy of the posttest can be seen in Figures C3-1 and C3-2.) The tests were marked by the children during the next session. The name of each child was recorded on the board along with his or her pretest and posttest scores; they were arranged according to the groups in which they worked.

To facilitate the comparison of the groups, group averages were calculated for both the pretest and posttest. The average scores were then converted to percentages with the pretest and posttest percentages subtracted to determine the amount of improvement or loss. The results are shown below.

	Pretest percentage correct	Posttest percentage correct	Percentage improvement
Reading and Research	30%	53%	23%
Memorization	48%	59%	11%
Practical Application	42%	70%	28%
Teacher-Taught	36%	48%	12%

We discussed the results of the children's investigations, noting that the Practical Application Group had made the greatest overall improvement, followed by the Reading and Research Group. I asked the children why they thought that the Teacher-Taught Group and Memorization Group scored so much lower than the other two groups. The class responded that these methods weren't as much fun and perhaps they had "goofed off." Students in the Practical Application Group thought that they had done well because they were working with "equipment," which made the subject matter easier to learn. The Reading and Research Group noted that they had enjoyed being able to work independently with a variety of printed materials and illustrations.*

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*The students might discuss whether another test should be given at a later date to check retention of the learning. They might then choose another topic for investigation and choose groups so that they could compare methods of learning for each individual as well as comparing group results. —ED.

4. LOG ON WAYS TO LEARN/TEACH

by Ida Campbell*
Hilsman Middle School, Grade 7
Athens, Georgia
(January-March 1975)

ABSTRACT

Students in this seventh-grade mathematics class began their investigation of the Ways to Learn/Teach challenge as they prepared to learn a new topic of study--geometry. They determined which methods to include in their experiment and then agreed to draw lots to form several groups. After two frustrating sessions were spent trying to prepare materials to learn a subject they did not know, the class decided to refocus their investigation and find the best way to learn geometry by teaching it to others. The students were first taught the topic by their teacher and then they worked in groups to prepare materials for each method. The children held several teaching sessions with sixth graders. Pretests and posttests were administered and scored, and the data were represented on graphs. Each group determined both the gains for its students and the average gain for the group and used the data to decide which method was best. Self-evaluations were written and the sixth-grade students were also surveyed for their evaulations of the techniques. During the last two months of the school year this class was challenged to use different learning methods to score a higher class average in the study of fractions than two other classes.

During a session in which my class was scheduled to begin studying geometry, I challenged the students to find the best way for our class to learn this new topic. This suggestion was met with quiet apprehension because the children were not sure what I mean, and they knew very little about geometry. Their interest grew steadily as we discussed the challenge. One student acted as recorder for the class and listed their ideas. The class quickly decided to break into groups to vote on the best way to learn geometry. One classmate noted what he observed to be a fallacy: voting on something about which you knew nothing. I suggested holding a brainstorming session, and the students came up with methods that we could use to learn geometry:

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1. learning centers
2. experimenting
3. boards and nails ("hands-on")
4. games
5. field trips
6. speakers
7. math book instruction

After much discussion the list was narrowed to four items: (1) learning centers, (2) games, (3) hands-on activities, and (4) textbook with instruction.

The next topic discussed was group selection. The children immediately rejected a classmate's suggestion that I select the groups. One student said that it was important that the "smart" people not end up in the same group because that group would have an unfair advantage over other groups, regardless of the method used. The rest of the class agreed and added a requirement that the groups be equal in number of members as well as in mathematical ability, if at all possible.

After a further discussion, one child suggested drawing lots to determine group membership. Because there were twenty-six children in the class and four groups, it was decided that two groups would have six members and two groups would have seven. Twenty-six slips of paper were prepared, each containing one of the four group names. These slips were placed in a box, and each student drew out one. A student recorded the membership of each group on the board as each child read his/her assignment.*

When I looked over the list after class, it became obvious that some students had chosen the group they wanted, disregarding the paper selected. At the next session we reviewed the results of the group selection, and the children also noted that the makeup of the groups didn't conform to their plans. We decided to repeat the procedure. The second round was successful, with no children switching groups.

The class then talked about some of the logistics of working in small groups. One student pointed out that some groups would be noisier than others; he suggested that they work in the hall. A classmate disagreed; the hall would be more appropriate for the quieter groups, he thought, because they would be less likely to disturb other classes.

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*To avoid biasing the group selection, the class might prepare twenty-eight slips, seven for each of the four groups. Only twenty-six would be drawn, however.--ED.

At my suggestion, the students discussed the idea of a pretest. They agreed it would be a good source of data and would enable them to evaluate progress if they made a comparison with posttest scores. Their only stipulation was that pretest scores not be counted in their grades.*

The students met in their groups to begin planning how they would use their methods to learn geometry. Because they were unfamiliar with the subject, they soon concluded that it would be difficult to make much headway. Therefore, they decided to get an overview of geometry by studying their math texts. Nevertheless, frustration began to build as the students tried to apply their limited knowledge to specific learning activities.

After two periods of little progress, I called the groups to a general meeting, and together we worked out a better plan of action. We discontinued the challenge of having the children find the best way to learn geometry on their own; instead, they would find the best way of learning geometry by teaching it to another class. First, I would instruct our class, and then when the students had a good knowledge of geometry, they would work in their four groups to devise activities to use in teaching others unfamiliar with the subject. In that way, we could still evaluate which method of learning geometry was best. The children were extremely pleased with their plan. Their enthusiasm returned and continued to be high.

When the study of geometry was completed, the children once again met in their groups and acquainted several new students with their activities. Discussions focused on the following questions I had written on the board.**

1. What geometry do *we* know?
2. Do we want to try to teach *all* we know to the sixth graders in three days?
3. If not, what *specific* things do we want to teach?
4. Should every group teach the same thing?

Toward the end of the session the entire class met, and I read aloud the notes of each group's discussion. Question four, "Should every group teach the same thing?" prompted a lengthy discussion. One student stated that if one group taught easier things, their "students" would make higher scores. A classmate suggested having each group teach different things with the sixth-graders rotating from group to group, thereby learning everything. I asked the class whether this rotation method would help us meet the challenge of finding the best way to teach geometry. One boy replied we could simply ask the sixth-graders which method had been the best way to learn. Another youngster, paying close attention to the conversation, observed that if the sixth-graders went to different groups each day, the end result would be a combination of all methods or more like a learning center. Voicing his agreement, another child added that sixth graders might choose one method as best just because they enjoyed it more than other methods.* The class considered all the comments and then decided that the groups would use their different methods to teach the same lesson.

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*The students might use the pretest scores to form balanced groups.--ED.

**A class discussion of what the groups were to do might bring out the same ideas.--ED.

Before ending the session, I asked the children what kind of data we would need to support our choice of the best method. One student made two suggestions that were accepted by the class. They were (1) to give the sixth graders a pretest to find out what they knew before our lessons, and (2) to conclude the teaching sessions with a posttest to find out what they had learned.

Choosing the topic to teach the sixth graders was our next concern. The children referred to their math textbooks and as they called out items they considered important, a student recorded the information on the board. When the list was completed, the children were surprised--everything they had studied about geometry was included. One student remarked that the class had spent several weeks learning about everything on the list but that they would have only three sessions with the sixth graders. A classmate came up with the idea of teaching the sixth graders only "a little" and letting them teach each other the rest. However, another child reminded everyone that having them teach each other was not the purpose of the challenge.

I refocused attention on the list of topics by asking the students what they felt we should do with such a comprehensive list. One youngster stated that the class should teach only the main points. She noted that what needed to be done was to go through the list and sort items according to their importance. That plan was accepted. The class voted on each item and those receiving a majority of the votes became the topics they would teach. The final list is shown below.

---

*The class might consider whether enjoyment of a method could be one criterion for judging a given method.--ED.

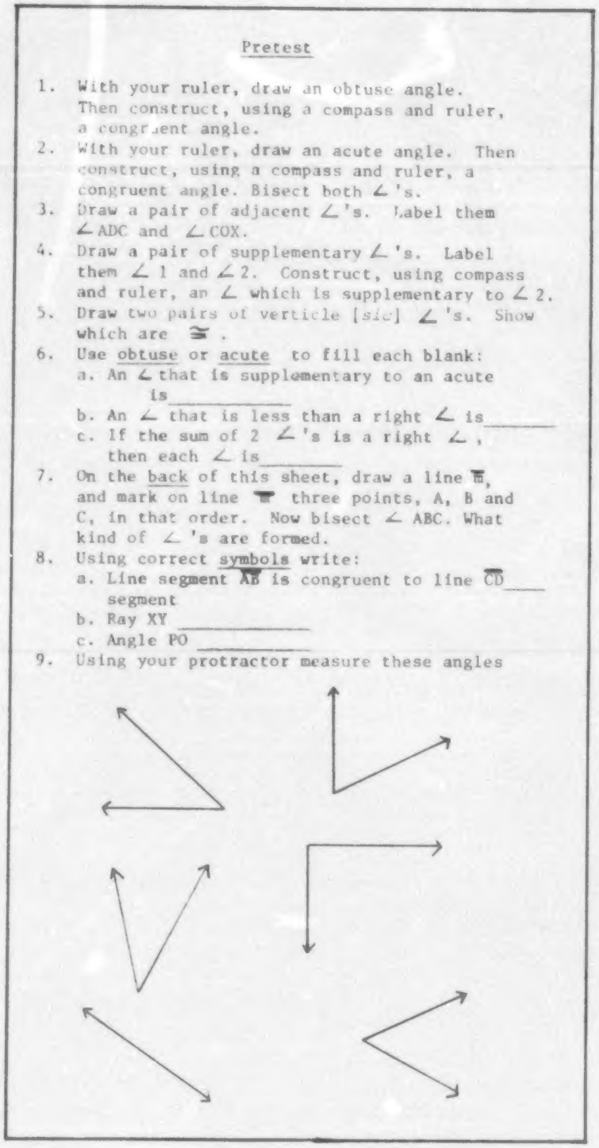
1. symbols
2. congruent angles
3. bisecting
4. planes
5. adjacent
6. points and lines
7. right angles
8. vertical
9. acute and obtuse
10. supplementary
11. vertex
12. perpendicular
13. measuring angles
14. correspond
15. interior and exterior

Several students were concerned that some of the topics would be too difficult for the sixth graders, but other students retorted that it was not fair to prejudge their ability. As the class ended, I asked the children to come to the next meeting with specific ideas on how their group could teach the topics.

School schedules limited the teaching preparation time to six days, including one weekend. Therefore, much of the work had to be done out of class with class time used for discussions and decision making. Every student copied the final list as a guideline to use at home. The class decided that I would design the pretest and the posttest.

At our next meeting the children immediately organized their groups to discuss each member's ideas, to make final plans, and to divide the tasks among group members. I visited each group and offered the following reminders:

1. Use class time wisely--make decisions in the group and assign tasks to be done at home.
2. Keep the list of things to be taught in front of you. As each person explains his/her ideas, ask yourself--
    a. Does it teach what we want it to teach?
    b. Does it use our teaching time to the best advantage?



Pretest

1. With your ruler, draw an obtuse angle. Then construct, using a compass and ruler, a congruent angle.
2. With your ruler, draw an acute angle. Then construct, using a compass and ruler, a congruent angle. Bisect both ∠'s.
3. Draw a pair of adjacent ∠'s. Label them ∠ADC and ∠COX.
4. Draw a pair of supplementary ∠'s. Label them ∠1 and ∠2. Construct, using compass and ruler, an ∠ which is supplementary to ∠2.
5. Draw two pairs of verticle [*sic*] ∠'s. Show which are ≅.
6. Use obtuse or acute to fill each blank:
   a. An ∠ that is supplementary to an acute is__________
   b. An ∠ that is less than a right ∠ is______
   c. If the sum of 2 ∠'s is a right ∠, then each ∠ is________
7. On the back of this sheet, draw a line $\overline{m}$, and mark on line $\overline{m}$ three points, A, B and C, in that order. Now bisect ∠ ABC. What kind of ∠'s are formed.
8. Using correct symbols write:
   a. Line segment $\overline{AB}$ is congruent to line $\overline{CD}$____ segment
   b. Ray XY ____________
   c. Angle PO ___________
9. Using your protractor measure these angles

Figure C4-1

The room was somewhat noisy, but the discussions sounded very productive. I sent two groups to other locations to work. As I circulated among the children, I was impressed by several factors:

1. Only two people in the room had failed to bring in written suggestions.
2. There was good, critical discussion in the groups.
3. By the end of the session, everyone had an assignment to prepare at home for the next meeting.

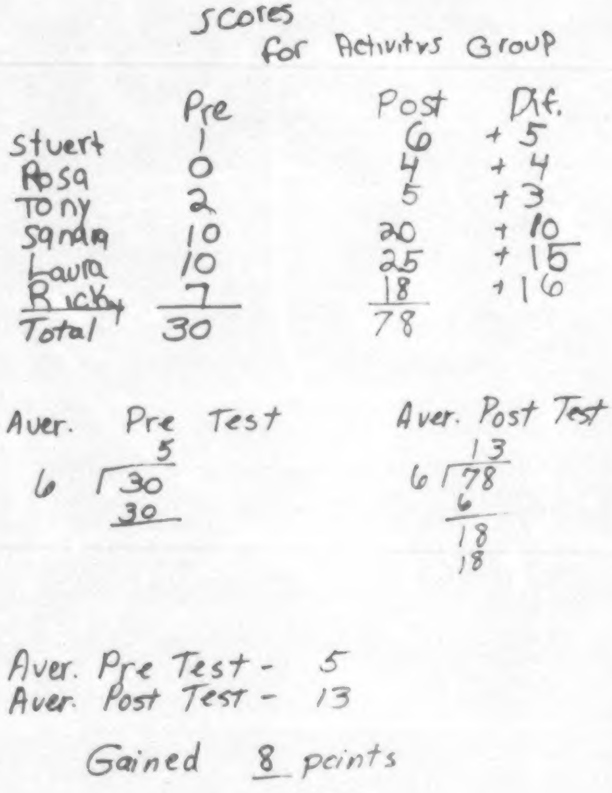
Group work continued for several sessions, and the children set Monday as their rehearsal day with their finished lessons. The groups were well organized and cooperative, and I was very pleased with the materials they prepared, which included transparencies and duplicating masters.

On rehearsal day we reviewed our teaching arrangements. The sixth-graders would come to our classroom for the sessions. The sliding curtain separating our room from the next room would be opened to allow us the space of two rooms. The sixth-grade teachers would have the classes divided into four heterogeneous groups, one for each of our four methods. As a last minute check, I distributed copies of the pretest and advised the groups to look it over and make sure that their materials covered all the topics mentioned. The remaining time was spent finishing the materials and rehearsing the lessons.

The following day I escorted the thirty-eight sixth graders to our classroom where they divided into four groups, as arranged by their teachers. My students first administered the pretest reproduced in Figure C4-1.

After the pretest was finished, my students taught the lessons they had planned, using dittos and student-made transparencies, compasses, protractors, and rulers. Student involvement and participation was high in three out of four groups; however the Books and Instruction Group had difficulty maintaining the sixth graders' interest.

Following this session two students from the Book Group discussed their problems with me. They felt it would be better to divide their sixth graders into several subgroups to accommodate their wide range of abilities. They asked me to grade the pretest papers and divide the group, but I suggested that we look over the papers together to see what the sixth graders already knew about geometry. The students



Scores
for Activitys Group

	Pre	Post	Dif.
Stuert	1	6	+5
Rosa	0	4	+4
Tony	2	5	+3
Sandra	10	20	+10
Laura	10	25	+15
Ricky	7	18	+16
Total	30	78	

Aver. Pre Test
5
6 ⟌30
30

Aver. Post Test
13
6 ⟌78
6
18
18

Aver. Pre Test - 5
Aver. Post Test - 13

Gained 8 points

Figure C4-2

SCORES

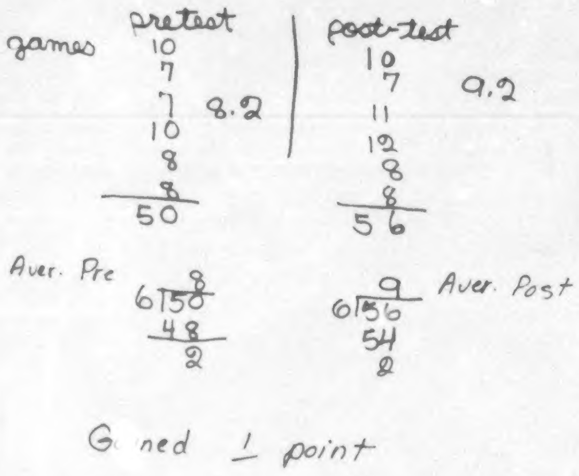
Books		Games		Activities		Learning Centers	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
8	18	10	10	1	6	20	22
14	24	7	7	0	4	7	17
8	19	7	11	2	5	0	0
0	3	10	12	10	20	9	11
10	22	8	8	10	25	11	17
7	10	8	8	7	18	11	17
3	5					9	28
12	16						
0	3						

Determining which group had learned the most about geometry was our next task. The students decided, after some discussion, to average the pretest and posttest scores for each group so that they could "even out" the large and smaller group sizes. They also agreed to discard scores of any sixth grader who had taken only one of the tests. One student in each group then read aloud the scores to group members who computed the pretest and posttest averages. We compiled the data on the board (as shown below) for easier comparison.

AVERAGE SCORES

Books		Games		Activities		Learning Center	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
7	13	8	9	5	13	9	16

Again I asked the students how we could decide which method had been most effective. One student recommended calculating the differences between the pretest and posttest scores and then finding the average gain for each group. This plan was adopted and the groups met to complete the computations. (Examples of the work done by two groups are shown in Figures C4-2 and C4-3.) Based on the average gain in scores shown below, we concluded that the Activities



	pretest	post-test
games	10	10
	7	7
	7	11
	10	12
	8	8
	8	8
	50	56
	8.2	9.2

Aver. Pre $6\overline{)50}$ = 8, 48, 2

Aver. Post $6\overline{)56}$ = 9, 54, 2

Gained 1 point

Figure C4-3

agreed to this; they also decided to revise their list of the topics to be taught the next day and to go over the list with other committee members.

I realized that an important component of our investigations had not been worked into our schedule--evaluation and adjustment of plans. It was too late, however, to reschedule the sixth-grade students to make more time available. Nevertheless, my students quickly understood both the importance of being well organized and the frustrations that can occur in teaching.

The following day I again escorted the sixth-grade students to our classroom. They immediately joined my seventh-grade students to begin their lessons. Members of the Games Group appeared hesitant about what to teach; they felt that the sixth graders in their group already had a good knowledge of geometry. They divided the sixth graders into two subgroups--boys and girls--for the remainder of the sessions, and I noticed that the girls did a great deal of instructing. The sixth-grade members of the group were attentive throughout the teaching sessions.

The Learning Centers Group had developed three centers, and the sixth-grade students rotated among them. As they had planned, the Book and Instruction Group divided their students into two groups, both working with our math textbook. Members of the Activity Group had the sixth-grade students draw various angles at the chalkboard. This was followed by a Bingo game using geometric symbols on the cards and finally, a hands-on lesson on bisecting an angle using a compass and ruler.

In the final teaching session, all four groups reviewed the materials they had covered the previous two days. Then my students administered the posttest which was the same as the pretest.

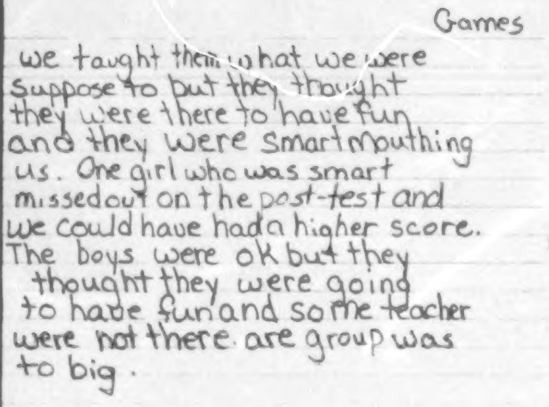
Grading the posttests and pretests took us a full session. Each test score was calculated by subtracting the number of incorrect answers from twenty-eight, a perfect score. One member of each group read the grades from the top of the paper and recorded the pretest and posttest scores for each individual in the group. The results are shown below.

Group had been most successful.*

AVERAGE GAIN --- PRETEST VS. POSTTEST

Books	6
Games	1
Activities	8
Learning Centers	7

I then asked the students to meet in their groups to decide why they thought the data resulted as it did; for example, whether or not the sixth-grade children were involved in the sessions, whether the group was well-organized and the instruction clear. Later we met together for a follow-up discussion during which each group shared its thoughts with the entire class. Throughout this discussion the children referred to their data and tried to listen critically to their classmates. (A copy of one group's self-evaluation is shown in Figure C4-4.)



Games

we taught them what we were
suppose to but they thought
they were there to have fun
and they were smart mouthing
us. One girl who was smart
missed out on the post-test and
we could have had a higher score.
The boys were ok but they
thought they were going
to have fun and some teacher
were not there are group was
to big.

Figure C4-4

These students wanted me to compare their results with those of my other two classes who were also working on Ways to Learn/Teach. I asked my students whether they could think of a way to represent our data so that everyone in all the classes could see our results. Many students recommended drawing graphs. We had not yet discussed graphing in our math class and, although most children said they knew how to make a graph, it was necessary to hold a discussion and skill session on graphing.

---

*In comparing the results, the students might discuss whether remainders are important. This might lead to the introduction of the decimal system, rounding off, and significant figures. They might also discuss whether the differences among the groups might occur in another trial or whether it is something that happened as a matter of chance. See Background Paper on determining differences between two sets of data. Also, the students might compute and compare the percentage gains based on the pretest scores. These percentage gains are, approximately--

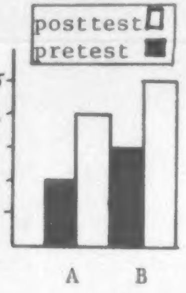
Books $\frac{6}{7}$ = 85.7%

Activities $\frac{8}{5}$ = 160.0%

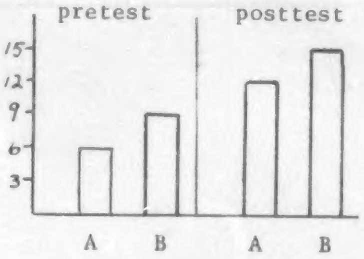
Games $\frac{1}{8}$ = 12.5%

Learning Center $\frac{6.5}{9.5}$ = 68.4%

The children suggested three different ways to graph the pretest and posttest data--two were bar graphs and one was a line graph. These students explained their ideas to their classmates, and I illustrated on the board the types of bar graph shown below.*



or



The students then worked on their graphs; a copy of one graph can be seen in Figure C4-5.

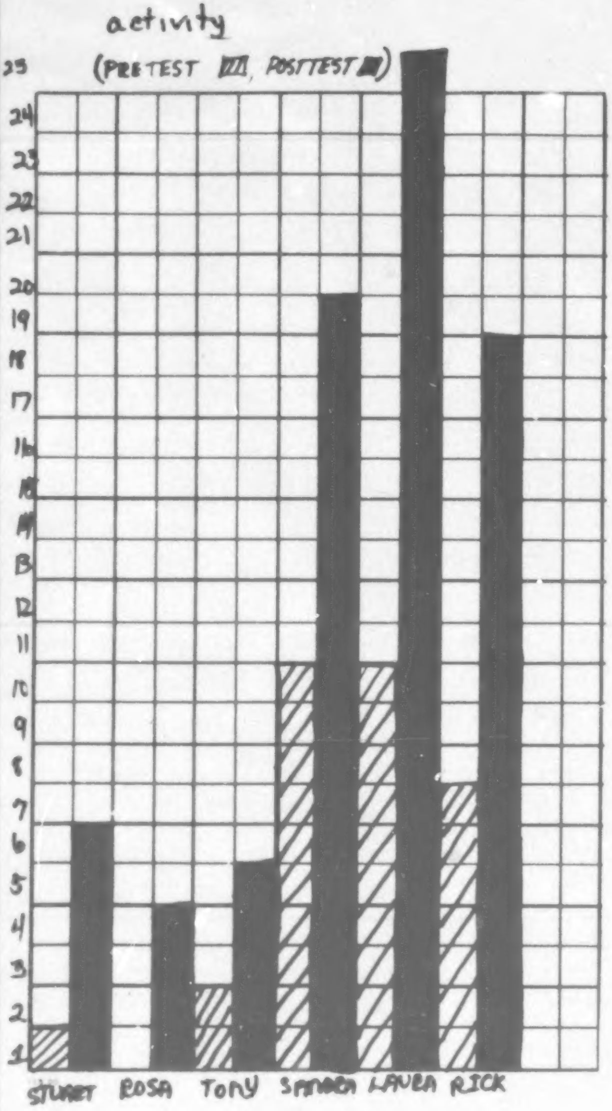


Figure C4-5

Before ending their work on the challenge, the class decided to survey the sixth graders involved in the experiment to determine which method of learning geometry they had liked best. The students composed the questions during a class meeting and one student then wrote them on a duplicating master (see Figure C4-6).

The survey was administered to the sixth graders by two volunteers, and the results were tallied and compiled by representatives from each group who then reported the information to the class (see below).

RESULTS OF SURVEY BY GROUP

	Activity		Learning Centers		Books		Games	
	YES	NO	YES	NO	YES	NO	YES	NO
1.	6	0	6	1	7	2	3	2
2.	6	0	5	2	6	3	2	3
3.	4	2	4	3	7	2	3	2
4.	5	1	5	1	5	2	5	1
5.	5	1	4	2	6	3	4	2
6.	1	4	1	4	2	5	3	5
7.	6	0	5	2	7	2	5	2
8.	5	1	4	3	7	3	2	3
9.	2	4	3	4	1	8	0	3

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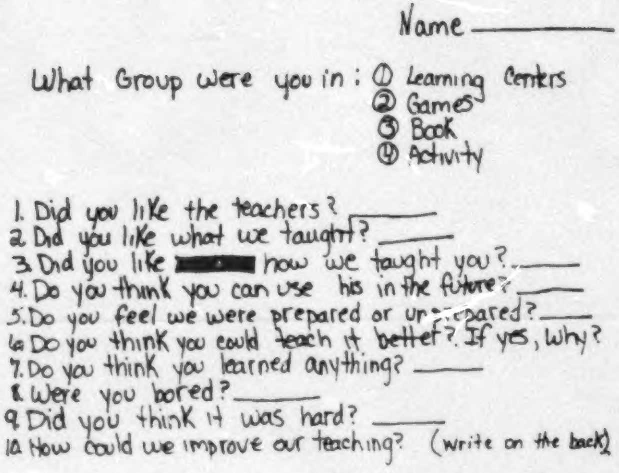
*The students might also compare the pretest and posttest averages on a line chart.--ED.



Name ________

What Group were you in: ① Learning Centers
② Games
③ Book
④ Activity

1. Did you like the teachers? ______
2. Did you like what we taught? ______
3. Did you like [redacted] how we taught you? ______
4. Do you think you can use his in the future? ______
5. Do you feel we were prepared or unprepared? ______
6. Do you think you could teach it better? If yes, Why?
7. Do you think you learned anything? ______
8. Were you bored? ______
9. Did you think it was hard? ______
10. How could we improve our teaching? (write on the back)

Figure C4-6

Referring to the survey data displayed on the board, the students looked for some correlation between the pretest and posttest scores and gains. As they reviewed the results, question by question, they observed that, in many instances, the data did correlate. For example, the Activity Group, which had shown the greatest gain, had the most positive response to the question, "Did you like the teacher?" The children noted that some of their survey questions had a direct bearing on the challenge while other questions were interesting in terms of responses but of little consequence to the results.

Before ending the session, I mentioned to the class that some of the representatives had found it difficult to tally the responses--some sixth graders had answered "maybe" or "sometime" rather than "yes" or "no." We briefly discussed (1) ways to improve our survey techniques (for example, design questions/responses to give more of a choice--very much, O.K., not much, terrible) and (2) whether one should make sure that people surveyed answer each question.*

With two months remaining in the school year and two mathematics topics to learn, I challenged my students to learn one new topic, fractions, better than my other two math classes. The students accepted the challenge, and we spent time designing the experiment. Children in the experimental class were to list the skills to be learned and then learn them through teacher instruction and skill sheets; the textbook would be used only for homework examples.** I told my other two classes, the control groups, that one of my classes had challenged them to get a higher class average at the end of the study of fractions. They were to learn the topic from their textbook with help as needed from me.

The children in the experimental class charted and averaged the scores from each of the tests as they were taken; students in all three classes were extremely interested in the class standings which were determined from each set of test scores and then posted. Based on grades from six tests given during the unit on fractions, the experimental class did earn a higher overall average. Although the average in one control class was significantly lower, the other control class average was very close to that of the experimental group. All three classes noted that they had enjoyed studying fractions, regardless of the outcome, and they were glad to have participated in the experiment.

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*The students might discuss whether the difference in total votes is important. They could make slope diagrams to compare the ratios of yes answers to the total vote for each group.--ED.

**The students might decide to try a third way, practical application.--ED.

5. LOG ON WAYS TO LEARN/TEACH

by Peggy Neal*
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Athens, Georgia
(March-May 1974)

ABSTRACT

This eighth-grade math class, designated by the school system as a group of low-ability students, began their investigations of the Ways to Learn/Teach challenge as they prepared to learn a new math topic--percentage. The children discussed the best ways to learn about percentage and then selected four methods: (1) learning centers, (2) games, (3) tapes and films, and (4) business (application). At their request, the teacher divided the class into four groups. Then, after taking a pretest, the groups spent fourteen sessions learning about percentage with their designated methods. A posttest was taken and gains and average gains of the group were calculated. The children next evaluated the results and suggested ways to improve future trials. Later in the semester students took a retention test, calculated scores and gains, and discussed the results. The group using practical application had greater gains on both the posttest and the retention test.

A class discussion concerning their next math topic, percentage, showed that the subject was new to all the students in my eighth-grade class. When I asked for suggestions of the best way to learn about percentage, the discussion became very lively. One student responded immediately that the best way for him to learn a new math topic was to study the textbook and then practice. Another student remarked that she learned best when the teacher worked problems on the board as she observed. A classmate joined the discussion, saying that the overhead projector helped him most in learning a new topic, and two other students observed that they learned better in math class when they worked in groups. Approximately half the class agreed that group work was also the best method for them.

Using games and audiovisual aids were also mentioned as possible ways to learn percentage. One student, who rarely participated in class discussions, became very interested; he said he would learn best by using other materials and subjects to which the study of percentage would apply.

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*Edited by USMES staff

Other students thought that using their two senses, hearing and sight, would be most effective; they could listen to a tape, then read, and finally fill in a practice sheet. At the end of the discussion I asked the children to consider whether we could find out which of all the suggestions was the best method.

The second session began with a restatement of the problem: "How can we find out which of the ways suggested is the best way to learn about percentage?" Several students thought we could use just one method and then try additional ones. After several minutes of discussion the class decided to conduct an experiment with several groups using different methods to learn about percentage. Then we would compare their results.

I asked the children how they thought the groups should be selected, and I suggested listing possible ways on the board with each child choosing the method he or she liked best. The children were very upset by this idea; they were bothered by the thought that most of the "smart" students would select the same group. They insisted that the groups have equal ability, with each child taking a pretest and a posttest to measure and record their improvement.

Deciding what criterion to use in forming groups caused quite a debate. Some students felt that the determining factor should be last quarter's grades, while others thought it should be the amount of work done rather than the grade received. Still others believed that the decision should be based on the results of a short pretest. The session ended with the class asking me to arrange the groups, subject to their approval, using whatever information was available to me.*

In our third meeting we discussed the groups I had selected. Several changes were requested and approved by the class. The following list of ways to learn about percentage was written on the board:

1. playing games
2. studying from a book, followed by working on examples
3. using learning centers
4. using tapes and films
5. business (application of percentage to money problems)
6. observing someone, followed by practice

---

*As there are so many variables involved, the students might agree to a random selection of students for the groups.—ED.

Pretest

Change to common fractions (simplify to lowest terms)
(1) 41% (2) 5% (3) 3% (4) 25% (5) 87%

Change to decimals
(1) 45% (2) 3% (3) 8% (4) 3.8% (5) 9%

Change to per cent
(1) $\frac{25}{100}$ (2) .35 (3) $\frac{43}{100}$ (4) $\frac{2}{\%}$ (5) .09

Solve the following
(1) 25% of 200 = ______ (2) ______% of 25 is 5
(3) 20 is 25% of ______ (4) 35% of 68 = ______
(5) 10 is ______% of 50
(6) Mary bought a dress at a 20% discount. If the dress cost $15, how much did she save?*
(7) Paul sold $150 worth of magazines at the school sale. If the school received a 20% commission, how much did Paul make for the school?

Figure C5-1

Group discussions of the approaches led to the selection of four methods: (1) learning centers, (2) games, (3) tapes and films, and (4) business (application). I ended the session by administering the pretest on percentages shown in Figure C5-1.

After class I corrected the pretests and filled the data (see below) to be used by the children at a later stage of their investigations.

Method	Scores
Centers	3, 1, 1, 2, 1
Games	5, 0, 0, 0
Tapes and Films	2, 2, 2, 3
Business	0, 3, 2

The children spent fourteen sessions working in their groups to learn about percentage using materials I had prepared.* On several occasions lessons were provided by my other classes who were also working on the Ways to Learn/Teach challenge. We also held three class discussions so that the groups could share their experiences with one another.

The Games Group began by playing a game of Concentration. Homemade cards contained percentages and their decimal or fractional equivalents; sample cars might be 10%, 25%, .10, .25, 1/10, .01. The usual rules of the game applied--cards were placed face down; children took turns uncovering two cards at a time; each matched pair resulted in a free turn; the person with the most pairs of cards at the end of the game was the winner. The students also worked on a sheet of basic concepts which were reinforced by the game.

"Hurry Up" was another game developed by the children. Each student was given a pack of answer cards--index cards with a number from 1 to 50 written on each one. A separate stack of cards containing problems such as "20% of 50 = ?" were turned face up one at a time. A student had one minute, using a timer, to calculate the correct answer and find it among his or her answer cards. Each correct answer earned one point. An example of one child's game sheet can be seen in Figure C5-2.

A third game used by the students was "Wastepaper Ball." It was planned to help students learn to calculate percentages. The children took turns throwing a wad of paper into

Game
Hurry up

1. 10% of 100 = 10
2. 30% of 30 = 9
3. 20% of 60 = 12
4. 20% of 80 = 16
X 5. 15% of 20 = 2
6. 40% of 60 = 24
7. 45% of 60 = 27
8. 40% of 90 = 36
X 9. 20% of 35 = 6
10.) 10% of 40 = 4
11.) 20% of 200 = 40
12.) 80% of 40 = 32
13.) 50% of 90 = 45

Figure C5-2

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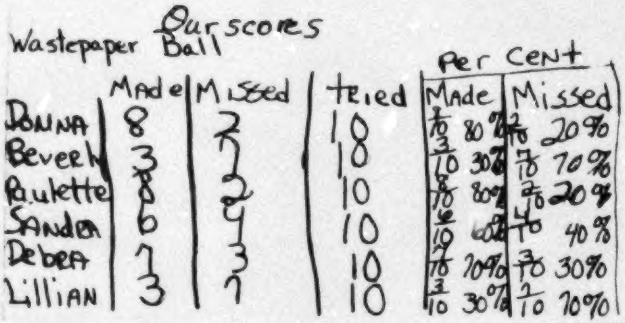
*The children might want to prepare some of their own materials.—ED.



Our scores
Wastepaper Ball

	Made	Missed	tried	Per Cent Made	Per Cent Missed
DONNA	8	2	10	$\frac{8}{10}$ 80%	$\frac{2}{10}$ 20%
Beverly	3	7	10	$\frac{3}{10}$ 30%	$\frac{7}{10}$ 70%
Paulette	8	2	10	$\frac{8}{10}$ 80%	$\frac{2}{10}$ 20%
SANdrA	6	4	10	$\frac{6}{10}$ 60%	$\frac{4}{10}$ 40%
DebrA	7	3	10	$\frac{7}{10}$ 70%	$\frac{3}{10}$ 30%
LilliAN	3	7	10	$\frac{3}{10}$ 30%	$\frac{7}{10}$ 70%

Figure C5-3

the wastebasket ten times from a distance of six to ten feet. Each child then had to calculate the percentage of throws that reached the basket. (See one child's record sheet in Figure C5-3.) A second round was played with seven shots per child.

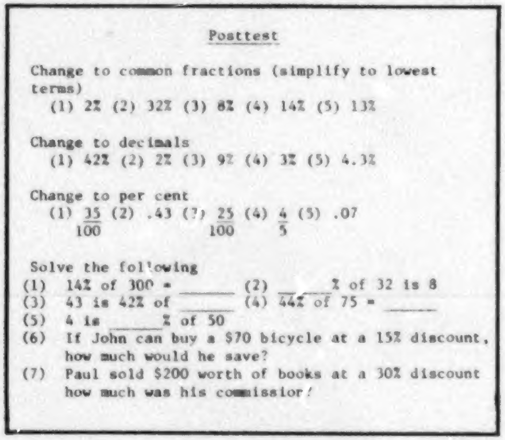
Members of the Tape and Film Group watched and then discussed a filmstrip on the basic concepts of percentage. The following session they used a cassette tape and a worksheet. The tape slowly explained the concepts and then time was allowed to complete the worksheet problems. Students in another class prepared another tape-recorded lesson. The tape instructed those listening to study a poster containing percentage equivalents. Then tips were given on how to apply equivalents to reduce calculation time for percentages; for example, children were encouraged to change percentages to equivalent fractions--20% of 35 = 1/5 x 35 = 7 . Worksheets were provided and answers were recorded on the tape.

The first materials for the Business Group contained an explanation of how to calculate a 3% sales tax. Using a menu from a local restaurant, the students were directed to place an order, determine the bill, and calculate the sales tax. Next, they were given a price list from a hardware store with the task to calculate the tax on each item. Activities for another session focused on a series of ten percentage problems, which were written on index cards and circulated to each group member. Answers were checked against an answer sheet. For another session the Business Group was given problems involving discount and an explanation of how to solve them. Again, they were instructed to check their work against an answer sheet.

The group of students using learning centers tried a variety of materials. A display board was used the first session along with a cassette tape with percentage problems and answers. Several sessions were spent using the overhead projector; transparencies contained problems with errors, which the children were asked to detect, as well as new problems to be solved. The final sessions were spent using the game approach. For BINGO, the call cards were written in the form of problems, such as 6 is ____% of 24.

During each session I circulated among the groups to talk about their progress and also about any problems they had encountered. Everyone agreed that it took several sessions to become accustomed to group work. By the twelfth session three groups, Games, Tapes and Films, and Business, expressed a desire for more variety. The majority of students felt that using several techniques was more conducive to learning than using the same method each day, but they agreed to continue in their particular groups for the two remaining sessions. (However, their opinion about the correlation between learning and the variety of methods was not substantiated by the data gathered on the four groups' progress.)

At the end of the fourteenth session I gave the groups the posttest shown in Figure C5-4.



Posttest

Change to common fractions (simplify to lowest terms)
(1) 2% (2) 32% (3) 8% (4) 14% (5) 13%

Change to decimals
(1) 42% (2) 2% (3) 9% (4) 3% (5) 4.3%

Change to per cent
(1) $\frac{35}{100}$ (2) .43 (3) $\frac{25}{100}$ (4) $\frac{4}{5}$ (5) .07

Solve the following
(1) 14% of 300 = ______ (2) ______% of 32 is 8
(3) 43 is 42% of ______ (4) 44% of 75 = ______
(5) 4 is ______% of 50
(6) If John can buy a $70 bicycle at a 15% discount, how much would he save?
(7) Paul sold $200 worth of books at a 30% discount how much was his commission?

Figure C5-4

For our next session I had written on the board the following test information and four questions:

SCORES

Centers		Games		Tapes & Films		Business	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
3	11	5	13	2	12	0	11
1	14	0	14	2	10	3	15
1	12	0	10	2	10	2	12
2	9	0	12	3	15		
1	12						

QUESTIONS

1. Which group did best?
2. How can you tell?
3. What were the things that your group did that helped you most?
4. What were the things that helped you least?

The children met in their groups to discuss the data, the questions, and the relationship of each to the class challenge, "What would be the best way for us to learn about percentage?" Midway through the session we reassembled to share our observations. I asked the children why they had taken a pretest at the beginning of their investigations. Some students felt it had been done to help determine the best possible groups. After some discussion, the children remembered that the pretest had been intended to help determine the amount of progress made by each student and consequently by each group.

I then directed the children's attention to the first question, "Which group did best?" Several students suggested adding the number of correct answers within each group on the posttest and comparing the totals Many students felt that the pretest scores should also be included in the evaluation. One student's idea was accepted by the class: we would determine the average gain between the pretests and posttests of each group and then compare them. The children completed the calculations (see below), and before we adjourned, I asked them to think about the results--what conclusions could be made and what factors might have influenced the outcome?*

AVERAGE GAIN--PRETEST VS. POSTTEST

Centers	10
Games	11
Tapes and Films	9 1/2
Business	11

During the next session the class considered whether the investigations had answered our original question about ways to learn percentage.** We talked about several factors that might have affected the outcome, including attendance, amount of work completed, and quality of materials used. The consensus of the class was that the different factors balanced each other, resulting in an effective experiment.***

The discussion continued to focus on variables affecting the test results rather than on whether the differences in the gains were significant. I referred the class to our data and asked the children whether they felt that the scores justified our conclusion that learning about percentage through business (practical application) was the best way. Most of the students felt that our conclusion was justified.

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*If the groups were picked by random selection, the class might take a second posttest. The gains of the groups could be shown to be significantly different if the groups' gains on the second posttest were in the same order as on the first posttest.--ED.

**The children might discuss the reason for learning percentage and determine what questions on the tests were related to this reason. An item-by-item analysis might then be carried out to see whether any group learned these questions better than the other groups.--ED.

***The students might check the average student hours spent by each group on their work.--ED.

Before the session ended the class discussed changes they would make in later investigations. They suggested that accurate attendance records be kept, in addition to a log and check sheet to be sure that each student took both the pretest and posttest. I asked for a hand vote on the following questions:

1. Do you think that learning about percentage in business is the best way to learn about percentage?

   Yes 14 No 3

2. Did our experiment answer this questions?

   Yes 13 No 4

3. Did you like the study we did?

   Yes 16 No 1

Two months later when we were reviewing all the math topics studied during the year, we again discussed our Ways to Learn/Teach challenge. We went over the measuring of percentage, changing percentages to decimals and fractions, and solving different types of percentage problems. I asked the students how they thought they would do if I gave them another test on percentage--whether the results for the four groups would be the same as on the posttest. I suggested that they take a retention test to measure how much they remembered about percentage, and the students agreed it was an interesting idea. That afternoon they took the test shown in Figure C5-5.

Per Cent Test
(2 Months Later)

Change to fractions:
(1) 13% (2) 23% (3) 5% (4) 3% (5) 2%

Change to decimals:
(1) 14% (2) 25% (3) 3% (4) 5% (5) 45%

Change to per cent:
(1) $\frac{2}{100}$ (2) .14 (3) .05 (4) $\frac{4}{5}$ (5) .35

Solve:

(1) 15% of 35
(2) 25% of 12
(3) 42% of $16.32
(4) 15 is __% of 60
(5) 10 is __% of [illegible]
(6) Paul bought a $50 basketball goal at a 10% discount. How much did he save?
(7) John sold magazines for a 15% commission. If he sold $400 worth of magazines, how much did he make?

Figure C5-5

Before the next session I graded the retention tests and put the raw scores on the board.

SCORES

	Pretest	Posttest	Retention test
Learning Centers	3	11	12
	1	14	13
	1	12	12
	2	9	13
	1	12	12

Games	5	13	17
	0	14	7*
	0	10	10
	0	12	10
Tapes & Films	2	12	13
	2	10	12
	2	10	10
	3	15	13
Business	0	11	16
	3	15	21
	2	12	14

After the class had arrived and examined the data, I asked which group had the best retention of percentage after two months. One student observed that all members of the Business Group had improved their scores whereas some members of other groups had lost points. At one student's suggestion, we repeated our method of finding the average group gains from pretest to posttest. The children calculated the averages for the retention test and then compared them to the posttest.

	Posttest	Retention Test
Learning Centers	10	10 4/5
Games	11	9 3/4 *
Business	11	15 1/3
Tapes & Films	9 1/2	9 3/4

Together we analyzed the data, noting that the Games and Business Groups had equal averages from the pretest to posttest but that the Business Group had a significant increase in the average from pretest to retention test. Members of the Business Group attributed their retention to the fact that they had really enjoyed their method of learning percentage and therefore had remembered what they had learned.

My students showed a marked improvement in their behavior both during and after their work on the Ways to Learn/Teach challenge. Their interest was high throughout their investigations, and their ability to reason improved. After completion of the challenge-related activities, they gave more thought to what and how they learned, and several students began to comment on methods we later used in our class.*

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*The students might look at the results to spot any possible errors in grading. It seems unlikely that one student in the Games Group would drop 50% when the others either gained or dropped only slightly.--ED.

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*The students might discuss whether certain individuals might learn better using one of the ways. The class might decide to choose another topic for investigation and compare individual as well as group results.--ED.

D. References

1. LISTS OF "HOW TO" SERIES

The *USMES "How To" Series* are written resources that help children learn skills they need to solve real problems (e.g., designing an opinion survey, drawing various types of graph).

"HOW TO" CARDS

Below are listed the current "How To" Card titles that students working on the Ways to Learn/Teach challenge may find useful. A complete listing of both the "How To" Cards and the Design Lab "How To" Cards is contained in the USMES Guide. In addition, the Design Lab Manual contains the list of Design Lab "How To" Cards.

GRAPHING

GR 1 How to Make a Bar Graph Picture of Your Data
GR 2 How to Show the Differences in Many Measurements of the Same Thing by Making a Histogram
GR 4 How to Decide Whether to Make a Bar Graph Picture or a Line Graph Picture of Your Data
GR 5 How to Find Out If There Is Any Relationship Between Two Things by Making a Scatter Graph
GR 7 How to Show Several Sets of Data on One Graph

PROBABILITY AND STATISTICS

PS 2 How to Record Data by Tallying
PS 3 How to Describe Your Set of Data by Finding the Average
PS 4 How to Describe Your Set of Data by Using the Middle Piece (Median)
PS 5 How to Find the Median of a Set of Data from a Histogram

RATIOS, PROPORTIONS, AND SCALING

R 1 How to Compare Fractions or Ratios by Making a Triangle Diagram*

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*Now called slope diagram

BEGINNING "HOW TO" SERIES

The cartoon-style format of this series helps younger children and those with reading difficulties acquire the skills and knowledge they may need during work on Ways to Learn/Teach.

COLLECTING DATA

"How To" Record Data
"How To" Do an Experiment
"How To" Make an Opinion Survey
"How To" Choose a Sample

GRAPHING

"How To" Choose Which Graph to Make
"How To" Make a Bar Graph
"How To" Make a Bar Graph Histogram
"How To" Make a Line Chart
"How To" Make a Scatter Graph
"How To" Make a Slope Diagram

SIMPLIFYING DATA

"How To" Find the Median
"How To" Find the Average

INTERMEDIATE "HOW TO" SERIES

This booklet-style series covers in more detail essentially the same information as the *Beginning "How To" Series* with a few booklets on additional skills. This series requires a greater reading skill and gives students a chance to read something they have a need to read. Those pertinent to Ways to Learn/Teach are listed below.

COLLECTING DATA

"How To" Collect Good Data
"How To" Record Data
"How To" Do an Experiment
"How To" Make an Opinion Survey
"How To" Choose a Sample

GRAPHING

"How To" Choose Which Graph to Make
"How To" Make a Bar Graph
"How To" Make a Histogram
"How To" Use Graphs to Compare Two Sets of Data

SIMPLIFYING DATA

"How To" Tell What Your Data Show
"How To" Find the Median
"How To" Find the Mean
"How To" Find the Mode
"How To" Find Different Kinds of Ranges
"How To" Use Key Numbers To Compare Two Sets of Data

LIST OF BACKGROUND PAPERS

As students work on USMES challenges, teachers may need background information that is not readily accessible elsewhere. The Background Papers fulfill this need and often include descriptions of activities and investigations that students might carry out.

Below are listed titles of current Background Papers that teachers may find pertinent to Ways to Learn/Teach. The papers are grouped in categories shown, but in some cases the categories overlap. For example, some papers about graphing also deal with probability and statistics.

The Background Papers are being revised, reorganized, and rewritten. As a result, many of the titles will change.

GRAPHING

GR 4 Representing Several Sets of Data on One Graph by Betty Beck
GR 6 Using Scatter Graphs to Spot Trends by Earle Lomon
GR 7 Data Gathering and Generating Graphs at the Same Time (or Stack 'Em and Graph 'Em at One Fell Swoop!) by Edward Liddle

GROUP DYNAMICS

GD 2 A Voting Procedure Comparison That May Arise in USMES Activities by Earle Lomon

PROBABILITY AND STATISTICS

PS 4 Design of Surveys and Samples by Susan J. Devlin and Anne E. Freeny
PS 5 Examining One and Two Sets of Data Part I: A General Strategy and One-Sample Methods by Lorraine Denby and James Landwehr
PS 6 Examining One and Two Sets of Data Part II: A Graphical Method for Comparing Two Samples by Lorraine Denby and James Landwehr

RATIOS, PROPORTIONS, AND SCALING

R 1 Graphic Comparison of Fractions by Merrill Goldberg
R 2 Geometric Comparison of Ratios by Earle Lomon

3. BIBLIOGRAPHY OF NON-USMES MATERIALS

The following books are references that may be of some use in teaching Ways to Learn/Teach. A list of references on general mathematics and science topics can be found in the USMES Guide.

Ellis, Arthur, and Ryan, Frank. *Instructional Implications of Inquiry*. Englewood Cliffs: Prentiss Hall.

Huff, Darrell. *How to Lie with Statistics*. New York: W.W. Norton and Company, Inc., 1954. 142 pages.
Written as a defense against the misuse of statistics, this book alerts the general public to the positive as well as the negative potential of statistics.

Moroney, M.J. *Facts from Figures*. Baltimore, Maryland: Penguin Books, Ltc., 1968. 472 pages.
A comprehensive introduction to statistics.

Ring, Arthur. *Planning and Producing Handmade Slides and Filmstrips for the Classroom*. Lear Siegler, Inc., Fearon Publishers (6 Davis Drive, Belmont, California 94002), 1974.
Techniques for making simple handmade slides and filmstrips in the classroom without a camera, using inexpensive materials, such as acetate film, Thermofax transparency. Master worksheets for both slides and filmstrips included with advice for making presentations.

Slonim, Morris J. *Sampling*. New York: Simon and Schuster, 1960. 144 pages.
An explanation of the basic principles involved in sampling and a discussion of the potential values of sampling as an effective way of quickly obtaining reliable information.

Tanur, Judith M. et al. *Statistics: A Guide to the Unknown*. San Francisco: Holden-Day, Inc. 1972. 430 pages.
An exploration of ways that applied statistics could be introduced into high school and college curricula. Much attention is given to discussing contributions of statistics to our daily lives.

Mosteller, Frederick et al. *Statistics By Example*. Reading, Massachusetts: Addison-Wesley Publishing Co., 1973.

All four books in the series place a heavy emphasis on real problems with real data.

Exploring Data--how to organize data; introduction of elementary probability where the ability to count is a sufficient starting point.

Weighing Chances--develops probability methods; introduces the idea of scatter and residuals to analyze data.

Detecting Patterns--discusses standard statistical devices such as normal distribution, the chi-square test, regression methods.

Finding Models--encourages the student to develop models as structures for data so that any departures from the models can be identified and new models created.

4. GLOSSARY

The following definitions may be helpful to a teacher whose class is investigating a Ways to Learn/Teach challenge. Some of the words are included to give the teacher an understanding of technical terms; others are included because they are commonly used throughout the resource book.

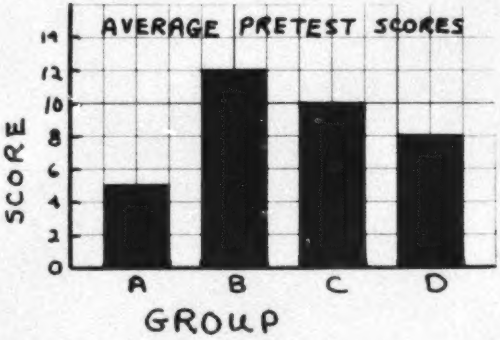
These terms may be used when they are appropriate for the children's work. For example, a teacher may tell the children that when they conduct surveys, they are collecting *data*. It is not necessary for the teacher or students to learn the definitions nor to use all of the terms while working on their challenge. Rather, the children will begin to use the words and understand the meanings as they become involved in their investigations.

Audiovisual	Relating to both hearing and sight.
Average	The numerical value obtained by dividing the sum of the elements of a set of data by the number of elements in that set. Also called the mean.
Bias	A deviation in the expected values of a set of data, often occurring when some factor produces one outcome more frequently than others.
Conversion	A change from one form to another. Generally associated in mathematics and science with the change from one unit of measure to another or the change from one form of energy to another.
Correlation	A relation between two sets of data.
Data	Any facts, quantitative information, or statistics.
Distribution	The spread of data over the range of possible results.
Event	A happening; an occurrence; something that takes place. Example: conducting a teaching lesson with kindergarten students.
Frequency	The total number of times a certain event has occurred.
Graph	A drawing or a picture of one or several sets of data.

Bar Graph

A graph of a set of measures or counts whose sizes are represented by the vertical (or horizontal) lengths of bars of equal widths or lines. Example: average group scores on the pretest.

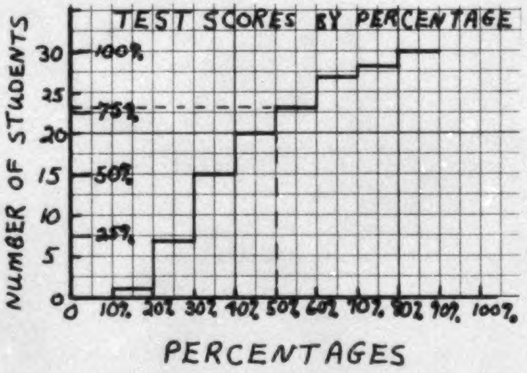
GROUP	AVERAGE SCORE
A	5
B	12
C	10
D	8



Cumulative Distribution Graph

A graph that can be constructed from a histogram by computing running totals from the histogram data. The first running total is the first value in the histogram data (see table of values). The second running total is the sum of the first and second values of the histogram, the third is the sum of the first, second, and third values, and so on. The horizontal scale on the graph is similar to that of the histogram; the vertical scale goes from 0 to the total number of events observed or samples taken (in the example, the total number of students who made certain scores on a test). Each vertical distance on the graph shows the running total for the value shown on the horizontal scale; thus the graph below indicates that 23 students (or about 77% of the students) had test scores of 60% or less.

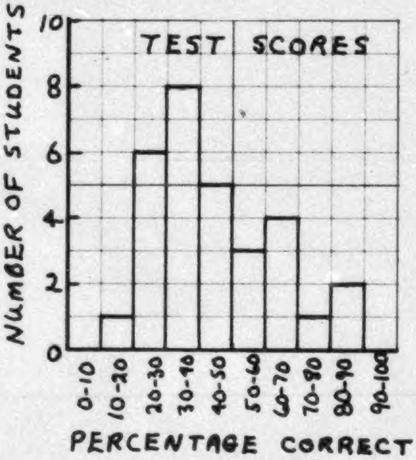
SCORE (%)	TOTAL NUMBER OF STUDENTS
10% or less	0
20% " "	1
30% " "	7
40% " "	15
50% " "	20
60% " "	23
70% " "	27
80% " "	28
90% " "	30
100% " "	30



Histogram

A type of bar graph that shows the distribution of the number of times that different measures or counts of the same event have occurred. A histogram always shows numerical data on the horizontal axis. Example: the number of students who scored in different percentage ranges on a test.

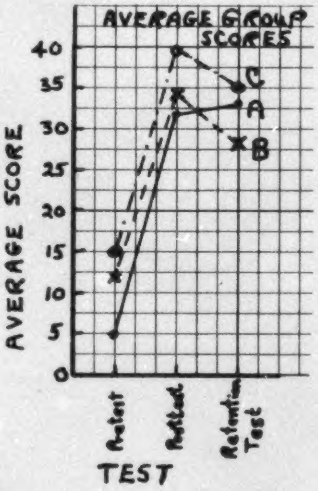
SCORE (%)	NUMBER OF STUDENTS
0-10	0
10-20	1
20-30	6
30-40	8
40-50	5
50-60	3
60-70	4
70-80	1
80-90	2
90-100	0



Line Chart

A bar graph that is represented by circles, triangles, or crosses with lines connecting them so that it has the appearance of a line graph. (See *Line Graph*.) This is a useful representation when two or more sets of data are shown on the same graph. Example: test averages for three different learning methods.

TEST	AVERAGE SCORE		
	Group A	Group B	Group C
Pretest	5	12	15
Posttest	32	34	39
Retention Test	33	28	35



Line Graph

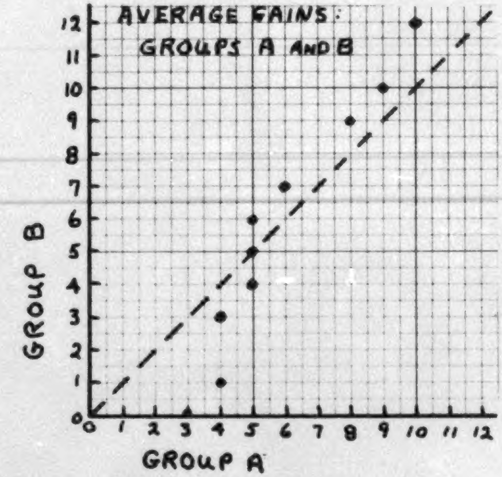
A graph in which a smooth line or line segments pass through or near points representing members of a set of data. Since the line represents an infinity of points, the variable on the horizontal axis must be continuous. If the spaces between the markings on the horizontal axis have no meaning, then the graph is not a line graph, but a line chart (see *Line Chart*).

Q-Q Graph

A graph that shows the comparison between the same type of data collected from two groups of people or from two different situations. Example: average points gained by members of two groups learning with different methods. The data for each set is ordered and the smallest measurement of one set plotted against the smallest of the other set, the second smallest against the second smallest, etc. The scatter of points is compared to a reference line, a dashed 45° line that represents data from two identical sets.

AVERAGE GAINS

Group A	Group B
3	0
4	1
4	3
5	4
5	5
5	6
6	7
8	9
9	10
10	12

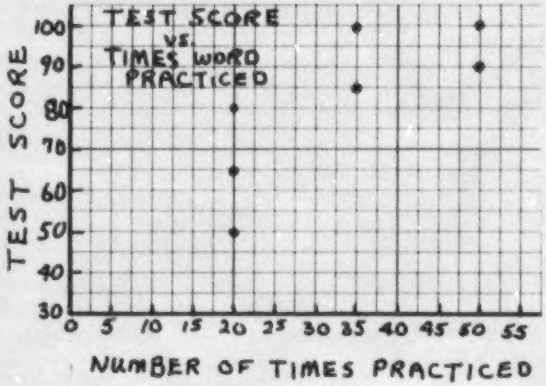


Scatter Graph

A graph showing a scatter of points, each of which represents two characteristics of the same thing. For example, in the graph below, the position of each point indicates the number of times spelling words were practiced and the student's score on the spelling test.

Scatter Graph (cont.)

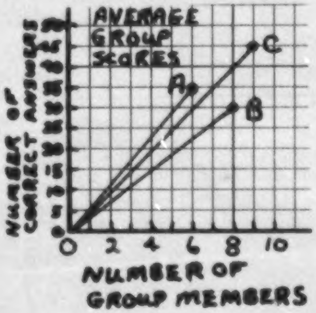
NUMBER OF TIMES WORD PRACTICED	TEST SCORE
20	50
20	65
20	80
35	85
35	100
50	90
50	100



*Slope Diagram**

A graphical means of comparing fractions or ratios. To represent the ratio a/b, plot the point (b,a) and draw a line from (b,a) to the origin, (0,0). The slope of this line represents the ratio a/b. By comparing slopes of different lines, different ratios can be compared; the steeper the line, the larger the ratio. For example, in the diagram below showing the ratio of the total group score on a test to the number of group members, the ratio of score to number of members for Group B is less than that for Group A or Group C; therefore, Group B has the highest group average.

GROUP	NUMBER OF MEMBERS	TOTAL SCORE
A	8	30
B	6	35
C	9	45



Histogram

See *Graph*.

Hypothesis

A tentative conclusion made in order to test its implications or consequences.

Inference

An assumption derived from facts or information considered to be valid and accurate.

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*Formerly called Triangle Diagram.

Mean	See *Average*.
Median	The middle value of a set of data in which the elements have been ordered from smallest to largest. The median value has as many elements above it as below it.
Mode	The element or elements in a set of data that occur most often.
Ordered Set	A set of data arranged from smallest to largest.
Per Cent	Literally per hundred. A ratio in which the denominator is always 100, e.g., 72 percent = 72/100 = 0.72 = 72% , where the symbol % represents 1/100.
Percentage	A part of a whole expressed in hundredths.
Population	Any group of objects (e.g., people) or events from which samples are taken for statistical measurement.
Probability	The likelihood or chance (expressed numerically) of one event occurring out of several possible events.
Proportion	A statement of equality of two ratios, i.e., the first term divided by the second term equals the third term divided by the fourth term, e.g., 5/10 = 1/2. Also a synonym for ratio: when two quantities are in direct proportion, their ratios are the same.
Quartile	
First	The first quartile is the value of the quarter-way piece of data in an ordered set of data.
Third	The third quartile is the value of the three-quarter-way piece of data in an ordered set of data.
Interquartile	The range or length of the middle 50% or an ordered set of data; the difference between the first and third quartile.
Range	The difference between the smallest and the largest values in a set of data.
Rank	To order the members of a set according to some criterion, such as size or importance. Example: to put pieces of data from smallest to largest.

Ratio	The quotient of two denominate numbers or values indicating the relationship in quantity, size, or amount between two different things. For example, the ratio of the number of children who made a certain score on a pretest to the total number of children who took the test might be 5/26 or 5:26.
Sample	A representative fraction of a population studied to gain information about the whole population.
Sample Size	The number of elements in a sample.
Set	A collection of characteristics, persons, or objects. Each thing in a set is called a member or an element.
Set Theory	The branch of mathematics that deals with the nature and relations of sets.
Slope Diagram	See *Graph*.
Statistics	The science of drawing conclusions or making predictions using a collection of quantitative data.
Tally	A visible record used to keep a count of some data, especially a record of the number of times one or more events occur. Example: a count of the number of different scores on a pretest.

E. Skills, Processes, and Areas of Study Utilized in Ways to Learn/Teach

The unique aspect of USMES is the degree to which it provides experience in the process of solving real problems. Many would agree that this aspect of learning is so important as to deserve a regular place in the school program even if it means decreasing to some extent the time spent in other important areas. Fortunately, real problem solving is also an effective way of learning many of the skills, processes, and concepts in a wide range of school subjects.

On the following pages are five charts and an extensive, illustrative list of skills, processes, and areas of study that are utilized in USMES. The charts rate Ways to Learn/Teach according to its potential for learning in various categories of each of five subject areas--real problem solving, mathematics, science, social science, and language arts. The rating system is based on the amount that each skill, process, or area of study within the subject areas is used--extensive (1), moderate (2), some (3), little or no use (-). (The USMES Guide contains a chart that rates all USMES units in a similar way.)

The chart for real problem solving presents the many aspects of the problem-solving process that students generally use while working on an USMES challenge. A number of the steps in the process are used many times and in different orders, and many of the steps can be performed concurrently by separate groups of students. Each aspect listed in the chart applies not only to the major problem stated in the unit challenge but also to many of the tasks each small group undertakes while working on a solution to the major problem. Consequently, USMES students gain extensive experience with the problem-solving process.

The charts for mathematics, science, social science, and language arts identify the specific skills, processes, and areas of study that may be learned by students as they respond to a Ways to Learn/Teach challenge and become involved with certain activities. Because the students initiate the activities, it is impossible to state unequivocally which activities will take place. It is possible, however, to document activities that have taken place in USMES classes and identify those skills and processes that have been used by the students.

Knowing in advance which skills and processes are likely to be utilized in Ways to Learn/Teach and knowing the extent that they will be used, teachers can postpone the teaching of those skills in the traditional manner until later in the year. If the students have not learned them during their USMES activities by that time, they can study them in the usual way. Further, the charts enable a teacher to integrate USMES more readily with other areas of classroom work. For example, teachers may teach fractions during math period when fractions are also being learned and utilized in the students' USMES activities. Teachers who have used USMES for several successive years have found that students are more motivated to learn basic skills when they have determined a need for them in their USMES activities. During an USMES session the teacher may allow the students to learn the skills entirely on their own or from other students, or the teacher may conduct a skill session as the need for a particular skill arises.

Because different USMES units have differing emphases on the various aspects of problem solving and varying amounts of possible work in the various subject areas, teachers each year might select several possible challenges, based on their students' previous work in USMES, for their class to consider. This choice should provide students with as extensive a range of problems and as wide a variety of skills, processes, and areas of study as possible during their years in school. The charts and lists on the following pages can also help teachers with this type of planning.

Some USMES teachers have used a chart similar to the one given here for real problem solving as a record-keeping tool, noting each child's exposure to the various aspects of the process. Such a chart might be kept current by succeeding teachers and passed on as part of a student's permanent record. Each year some attempt could be made to vary a student's learning not only by introducing different types of challenges but also by altering the specific activities in which each student takes part. For example, children who have done mostly construction work in one unit may be encouraged to take part in the data collection and data analysis in their next unit.

Following the rating charts are the lists of explicit examples of real problem solving and other subject area skills, processes, and areas of study learned and utilized in Ways to Learn/Teach. Like the charts, these lists are based on documentation of activities that have taken place in USMES classes. The greater detail of the lists allows teachers to see exactly how the various basic skills, processes, and areas of study listed in the charts may arise in Ways to Learn/Teach.

The number of examples in the real problem solving list have been limited because the list itself would be unreasonably long if all the examples were listed for some of the categories. It should also be noted that the example(s) in the first category--*Identifying and Defining Problems*--have been limited to the major problem that is the focus of the unit. During the course of their work, the students will encounter and solve many other, secondary problems, such as the problem of how to display their data or how to draw a scale layout.

Breaking down an interdisciplinary curriculum like USMES into its various subject area components is a difficult and highly inexact procedure. Within USMES the various subject areas overlap significantly, and any subdivision must be to some extent arbitrary. For example, where does measuring as a mathematical skill end and measurement as a science or a social science process begin? How does one distinguish between the processes of real problem solving, of science, and of social science? Even within one subject area, the problem still remains--what is the difference between graphing as a skill and graphing as an area of study? This problem has been partially solved by judicious choice of examples and extensive cross-referencing.

Because of this overlap of subject areas, there are clearly other outlines that are equally valid. The scheme presented here was developed with much care and thought by members of the USMES staff with help from others knowledgeable in the fields of mathematics, science, social science, and language arts. It represents one method of examining comprehensively the scope of USMES and in no way denies the existence of other methods.

REAL PROBLEM SOLVING	Overall Rating
Identifying and defining problem.	1
Deciding on information and investigations needed.	1
Determining what needs to be done first, setting priorities.	1
Deciding on best ways to obtain information needed.	1
Working cooperatively in groups on tasks.	1
Making decisions as needed.	1
Utilizing and appreciating basic skills and processes.	1
Carrying out data collection procedures--observing, surveying, researching, measuring, classifying, experimenting, constructing.	1
Asking questions, inferring.	1
Distinguishing fact from opinion, relevant from irrelevant data, reliable from unreliable sources.	1

REAL PROBLEM SOLVING	Overall Rating
Evaluating procedures used for data collection and analysis. Detecting flaws in process or errors in data.	1
Organizing and processing data or information.	1
Analyzing and interpreting data or information.	1
Predicting, formulating hypotheses, suggesting possible solutions based on data collected.	1
Evaluating proposed solutions in terms of practicality, social values, efficacy, aesthetic values.	1
Trying out various solutions and evaluating the results, testing hypotheses.	1
Communicating and displaying data or information.	1
Working to implement solution(s) chosen by the class.	1
Making generalizations that might hold true under similar circumstances; applying problem-solving process to other real problems.	1

KEY: 1 = extensive use, 2 = moderate use, 3 = some use, - = little or no use.

MATHEMATICS	Overall Rating
Basic Skills	
Classifying/Categorizing	2
Counting	1
Computation Using Operations	
Addition/Subtraction	1
Multiplication/Division	1
Fractions/Ratios/Percentages	1
Business and Consumer Mathematics/ Money and Finance	-
Measuring	1
Comparing	1
Estimating/Approximating/Rounding Off	1
Organizing Data	1
Statistical Analysis	1
Opinion Surveys/Sampling Techniques	-
Graphing	1
Spatial Visualization/Geometry	3
Areas of Study	
Numeration Systems	2
Number Systems and Properties	1
Denominate Numbers/Dimensions	1
Scaling	3
Symmetry/Similarity/Congruence	-
Accuracy/Measurement Error/ Estimation/Approximation	1
Statistics/Random Processes/Probability	1
Graphing/Functions	1
Fraction/Ratio	1
Maximum and Minimum Values	3
Equivalence/Inequality/Equations	1
Money/Finance	-
Set Theory	-

SCIENCE	Overall Rating
Processes	
Observing/Describing	1
Classifying	1
Identifying Variables	1
Defining Variables Operationally	1
Manipulating, Controlling Variables/ Experimenting	1
Designing and Constructing Measuring Devices and Equipment	3
Inferring/Predicting/Formulating, Testing Hypotheses/Modeling	1
Measuring/Collecting, Recording Data	1
Organizing, Processing Data	1
Analyzing, Interpreting Data	1
Communicating, Displaying Data	1
Generalizing/Applying Process to New Problems	1
Areas of Study	
Measurement	3
Motion	-
Force	-
Mechanical Work and Energy	-
Solids, Liquids, and Gases	-
Electricity	-
Heat	-
Light	-
Sound	-
Animal and Plant Classification	-
Ecology/Environment	-
Nutrition/Growth	-
Genetics/Heredity/Propagation	-
Animal and Plant Behavior	-
Anatomy/Physiology	-

SOCIAL SCIENCE	Overall Rating
Process	
Observing/Describing/Classifying	1
Identifying Problems, Variables	1
Manipulating, Controlling Variables/ Experimenting	1
Inferring/Predicting/Formulating, Testing Hypotheses	1
Collecting, Recording Data/Measuring	1
Organizing, Processing Data	1
Analyzing, Interpreting Data	1
Communicating, Displaying Data	1
Generalizing/Applying Process to Daily Life	1
Attitudes/Values	
Accepting responsibility for actions and results	1
Developing interest and involvement in human affairs	1
Recognizing the importance of individual and group contributions to society	1
Developing inquisitiveness, self-reliance, and initiative	1
Recognizing the values of cooperation, group work, and division of labor	1
Understanding modes of inquiry used in the sciences, appreciating their power and precision	1
Respecting the views, thought, and feelings of others	1
Being open to new ideas and information	1
Learning the importance and influence of values in decision making	1
Areas of Study	
Anthropology	-
Economics	-
Geography/Physical Environment	-
Political Science/Government Systems	-
Recent Local History	-
Social Psychology/Individual and Group Behavior	2
Sociology/Social Systems	3

LANGUAGE ARTS	Overall Rating
Basic Skills	
Reading	
Literal Comprehension: Decoding Words Sentences, Paragraphs	2
Critical Reading: Comprehending Meanings, Interpretation	1
Oral Language	
Speaking	1
Listening	1
Memorizing	-
Written Language	
Spelling	1
Grammar: Punctuation, Syntax, Usage	1
Composition	1
Study Skills	
Outlining/Organizing	1
Using References and Resources	2
Attitudes/Values	
Appreciating the value of expressing ideas through speaking and writing	1
Appreciating the value of written resources	2
Developing an interest in reading and writing	1
Making judgments concerning what is read	1
Appreciating the value of different forms of writing, different forms of communication	1

KEY: 1 = extensive use, 2 = moderate use,
3 = some use, - = little or no use

REAL PROBLEM SOLVING IN WAYS TO LEARN/TEACH

Identifying and Defining Problems	• Students identify the way they try to learn certain topics as a problem. • Students identify different ways to learn or to teach those topics. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables.*
Deciding on Information Needed	• After a discussion students decide they need to collect data on how much they know before studying and after studying with different methods or in different environments. • Students agree to conduct an opinion survey on preferred learning methods or preferred learning environments. • After analyzing pretest and posttest scores, students decide that data on retention would be helpful.
Determining What Needs to Be Done First, Setting Priorities	• Students select several learning methods and decide to take a pretest before dividing into groups to use the different methods or different environments. • Students decide that they have to learn about a topic before teaching it to others.
Deciding on Best Ways to Obtain Information Needed	• Students decide that by working in groups they can try out several learning methods or environments. • Students decide that a pretest and posttest will help them compare different learning methods or environments. • Students decide that random selection or using pretest results will produce groups of approximately equal abilities.
Working Cooperatively in Groups on Tasks	• Students form groups to prepare materials and to study or teach the topic using their selected methods or environments.
Making Decisions as Needed	• Students decide to have each group use a different method or environment so that several learning situations can be compared at one time.

Making Decisions as Needed (cont.)	• Students select the methods they will try by consensus or by a hand vote. • Students decide they will teach the topic to younger students. • Students define extent of each group's activities, e.g., Book Group will not use any worksheets. • Students decide to repeat their experiment on the same learning methods to obtain more data.
Utilizing and Appreciating Basic Skills and Processes	• Students add test scores and divide to find group averages. • Students draw graphs of test data. • Students look for factors that might affect the results of their learning experiment. • Students recognize that finding the best way to learn a topic can help other people besides themselves, namely, other classes with whom they share their findings and future students in their teacher's class. • Students give oral presentations to other classes. • See also MATHEMATICS, SCIENCE, SOCIAL SCIENCE, and LANGUAGE ARTS lists.
Carrying Out Data Collection Procedures--Opinion Surveying, Researching, Measuring, Classifying Experimenting, Constructing	• Students conduct opinion surveys to find out the best-liked learning methods. • Students look through library books to find information about their topic. • Students collect data by taking or administering pretests and posttests. • Students categorize items in their list of ways to learn to narrow the number of methods. • See also MATHEMATICS list: *Classifying/Categorizing; Measuring.* • See also SCIENCE list: *Observing/Describing; Classifying; Manipulating, Controlling Variables/Experimenting; measuring/Collecting, Recording Data.* • See also SOCIAL SCIENCE list: *Observing/Describing; Classifying; Manipulating, Controlling Variables/Experimenting; Collecting, Recording Data/Measuring.*
Asking Questions, Inferring	• Students ask whether one learning method or environment is better than another and they infer from collected data that one method or environment produces better results.

Asking Questions, Inferring (cont.)	• Students ask whether retention of learning is a factor to be considered and they infer from their data that some methods of learning produce better retention than other methods. • Students ask whether the same learning method is the best one for everyone and they infer from their data that some people learn better with different techniques. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Distinguishing Fact from Opinion Relevant from Irrelevant Data, Reliable from Unreliable Sources	• Students recognize the qualitative aspects of obtaining data from surveys as distinct from data they gather by measuring performance with different ways to learn. • Students recognize that using the median for group scores is not a good measure since it ignores very large or very small gains.
Evaluating Procedures Used for Data Collection and Analysis, Detecting Flaws in Process or Errors in Data	• Students discuss the manner in which they made group selections and decide that a random selection or using pretest results to balance the groups would produce a fairer result. • Students decide that total points gained by the groups will not result in a fair comparison when the groups have varying numbers of members. • Students decide that their opinion survey needs improvement and they discuss changes they can make. • Students decide to ask the teacher to prepare the pretest and posttest because they are learning geometry for the first time. • See also MATHEMATICS list: *Estimating/Approximating/Rounding Off.*
Organizing and Processing Data	• Students organize their test data according to methods used and record it on charts and graphs. • See also MATHEMATICS list: *Organizing Data.* • See also SCIENCE and SOCIAL SCIENCE lists: *Organizing, Processing Data.*

Analyzing and Interpreting Data	• Students find the average gain of each group using a different way to learn or a different environment. • Younger students draw slope diagrams to compare the gains of the groups. • Older students find and use the medians and middle ranges to compare the gains of the groups. • See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing; Maximum and Minimum Values.* • See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data.*
Predicting, Formulating Hypotheses, Suggesting Possible Solutions Based on Data Collected	• Students predict that the way to learn a certain topic that resulted in the greatest gain will produce better learning than the usual classroom procedure. • Students hypothesize that they will learn better when they use methods they like as indicated on opinion survey. • Students suggest that their most successful method be used as part of their regular math learning. • Students make suggestions about learning methods to other classes based on their test results. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*
Evaluating Proposed Solutions in Terms of Practicality, Social Values, Efficacy, Aesthetic Values	• Students discuss advantages and disadvantages of using their most successful learning techniques as part of their regular math curriculum. • Students discuss how they liked using different methods and whether one method is preferred over another.
Trying Out Various Solutions and Evaluating the Results, Testing Hypotheses	• Students work in groups using different methods to learn or teach a new topic and compare the results. • Students change groups so that everyone can use another method and compare the gains of these groups with the gains of the previous groups. • Students work in groups using the methods they like and compare individual gains with gains using other methods. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses/Modeling.* • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses.*

Communicating and Displaying Data of Information	• Students use charts and graphs to display test data. • Students use lessons they have devised to teach certain topics to another class. • See also MATHEMATICS list: *Graphing.* • See also SCIENCE and SOCIAL SCIENCE lists: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Working to Implement Solution(s) Chosen by the Class	• Students discuss with the teacher how they can use the most successful learning methods in their regular class. • Students make a presentation of their findings to the principal and other classes to encourage the use of their most successful ways to learn. • Students discuss with the teacher how they can set up a better environment for learning.
Making Generalizations That Might Hold True Under Similar Circumstances; Applying Problem-Solving Process to Other Real Problems	• Students who have drawn graphs to display test data more readily draw graphs in other instances. • Students apply skills and processes they have learned to resolve other classroom or school problems. • See also SCIENCE list: *Generalizing/Applying Process to New Problems.* • See also SOCIAL SCIENCE list: *Generalizing/Applying Process to Daily Life.*

ACTIVITIES IN WAYS TO LEARN/TEACH UTILIZING MATHEMATICS

Basic Skills

Classifying/Categorizing	• Categorizing characteristics of different ways to learn. • Categorizing characteristics of learning methods in more than one way. • Organizing and classifying sets of materials, activities, or information. • See also SCIENCE list: *Classifying*. • See also SOCIAL SCIENCE list: *Observing/Describing/Classifying*.
Counting	• Counting votes to decide which ways to learn/teach will be used. • Counting survey or questionnaire data on preferred learning methods. • Counting number of points scored by individuals and groups. • Counting number of minutes allotted for a teaching session. • Counting by sets to find a scale for graph axes.
Computation Using Operations: Addition/Subtraction	• Adding one-, two-, or three-digit whole numbers to find total number of points gained by each group. • Adding minutes when timing length of learning period. • Subtracting to find differences between predicted and actual test scores. • Subtracting to find difference between pretest and post-test scores. • Subtracting one-, two-, or three-digit whole numbers to find ranges for graph axes, to compare sets of test data. • Adding to find total tally of students who received a particular test score.
Computation Using Operations: Multiplication/Division	• Dividing to calculate average test score of each group. • Dividing to form groups with equal numbers of members. • Dividing to calculate ratios, fractions, or percentages. • Multiplying or dividing to find a scale for graph axes.
Computation Using Operations: Fractions/Ratios/Percentages	• Using mixed numbers when calculating average group scores. • Changing fractions to higher or lower terms (equivalent fractions) to compare average group scores.

Computation Using Operations: Fractions/Ratios/Percentages (cont.)	• Calculating ratios of number of correct answers to number of test questions, percentage of correct answers. • Calculating percentage gain from pretest to posttest, percentage of students who improved on the posttest.
Measuring	• Using arbitrary units (e.g., lengths of string or standard units) to measure dimensions for materials used in learning. • Using a calendar to time days for preparing materials and days for teaching; using a clock to time length of test; using a stopwatch to time length of tape-recorded information. • Reading stopwatches, clocks, rulers, meter sticks accurately. • See also SCIENCE list: *Measuring/Collecting, Recording Data*. • See also SOCIAL SCIENCE list: *Collecting, Recording Data/Measuring*.
Comparing	• Using the concepts of *greater than* and *less than* in making comparisons of test data. • Comparing quantitative data obtained from posttest and pretest. • Comparing data obtained from different groups. • Comparing qualitative data obtained from preference survey on learning methods with quantitative data obtained from test scores. • Comparing predicted and actual performance by different groups. • Making graphic comparisons of test data. • See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data*.
Estimating/Approximating/ Rounding Off	• Estimating number of students who will receive the same score on the retention test as on the posttest. • Determining when a measurement of the effectiveness of a learning method is likely to be accurate enough to show a significant difference among methods.
Organizing Data	• Tallying votes on priorities. • Tallying survey or questionnaire data on preferred learning methods.

Organizing Data (cont.)

- Tallying on bar graphs or histograms.
- Ordering real numbers on a number line or graph axis.
- Ordering the steps in a process.
- Ordering test data.
- See also SCIENCE and SOCIAL SCIENCE lists: *Organizing, Processing Data*.

Statistical Analysis

- Finding and comparing the average points gained or percentage gain of each group on the posttest and retention test.
- Assessing the predictability of a larger sample (e.g., the entire class, other classes) based on results of a small group of students.
- Determining medians and middle ranges of data on test score gains.
- Determining whether the difference between groups is significant by comparing medians of test score gains with largest middle range.
- Compiling quantitative data obtained from repeated experiments.
- See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data*.

Opinion Surveys/Sampling Techniques

- Conducting surveys on preferred ways to learn; defining data collection methods and the makeup and size of the sample.
- Devising methods of obtaining quantitative information about subjective opinions regarding ways to learn.
- Evaluating survey methodology, data obtained, and the size and type of samples.
- See also SCIENCE and SOCIAL SCIENCE lists: *Analyzing, Interpreting Data*.

Graphing

- Using alternative methods of displaying data, e.g., charts, graphs.
- Making a graph form--dividing axes into parts and deciding on an appropriate scale.
- Representing data on graphs.
  - Bar graph--average group scores on pretest.
  - Cumulative distribution graph--number of students who scored in a certain percentage range or less on a test.
  - Histogram--number of students who scored in different percentage ranges on a test.

Graphing (cont.)	• Line chart--group averages on pretest, posttest, and retention test. • Q-Q graph--average number of points gained by students using two different learning methods. • Scatter graph--number of times spelling word is practiced vs. student score on spelling test. • Slope diagram--number of group members compared to total points gained by different groups. • Obtaining information from graphs. • See also SCIENCE and SOCIAL SCIENCE lists: *Communicating, Displaying data*.
Spatial Visualization/Geometry	• Using geometric figures--for example, triangles, circles--to construct materials for learning. • Measuring and constructing alphabet letters from Tri-Wall, using rulers, compasses, and protractors. • Using spatial arrangements in designing worksheets.
Areas of Study	
Numeration Systems	• Using the decimal system in calculating average group gains. • Using fractions in calculating average group gains, dimensions for a board game.
Number Systems and Properties	• See *Computation Using Operations*.
Denominate Numbers/Dimensions	• See *Measuring*
Symmetry/Similarity/Congruence	• See *Spatial Visualization/Geometry*.
Accuracy/Measurement Error/ Estimation/Approximation	• See *Measuring* and *Estimating/Approximating/Rounding Off*.
Statistics/Random Processes/ Probability	• See *Statistical Analysis*.
Graphing/Functions	• See *Graphing*.

Fraction/Ratio	• See *Computation Using Operations: Fractions/Ratios/Percentages*.
Maximum and Minimum Values	• Using slope diagrams to find highest group average gain. • Finding the learning method that produces maximum results.
Equivalence/Inequality/Equations	• See *Comparing* and *Computation Using Operations*.
Set Theory	• See *Classifying/Categorizing*.

ACTIVITIES IN WAYS TO LEARN/TEACH UTILIZING SCIENCE

Process	
Observing/Describing	• Observing that some students learn a certain topic more quickly and easily than others. • See also SOCIAL SCIENCE list: *Observing/Describing/ Classifying.*
Classifying	• Classifying different methods of learning according to materials used. • See also MATHEMATICS list: *Classifying/Categorizing.* • See also SOCIAL SCIENCE list: *Observing/Describing/ Classifying.*
Identifying Variables	• Identifying learning method used as the variable to be changed in an experiment assessing different methods. • Identiyfing length of time, surroundings, and age and learning ability of students as variables to be controlled in the experiment. • Identifying amount learned using different methods as the variable to be measured. • See also SOCIAL SCIENCE list: *Identifying Problems, Variables.*
Defining Variables Operationally	• Defining learning ability as previous grade in subject or the score attained on a pretest. • Defining amount learned as difference between pretest and posttest scores.
Manipulating, Controlling Variables/Experimenting	• Designing and conducting an experiment to determine which method of learning a certain topic is best for the class as a whole. • Setting up groups of students to use different methods to learn a certain topic. • Keeping the average learning ability of the groups using the different methods the same (or as nearly the same as possible). • Keeping the amount of time spent learning by the different methods the same.

Manipulating, Controlling Variables/Experimenting (cont.)	• Conducting other experiments to determine the amount of retention according to different learning methods, to determine best methods for different individuals, and to determine the effect of noisy surroundings on learning. • Controlling all factors except the one being assessed in these experiments. • See also SOCIAL SCIENCE list: *Manipulating, Controlling Variables/Experimenting*.
Designing and Constructing Measuring Devices and Equipment	• Constructing devices needed for learning a certain topic.
Inferring/Predicting/Formulating Testing Hypotheses/Modeling	• Inferring from data that a certain method of learning is better than others for the whole class. • Predicting that noisy surroundings inhibit learning. Testing prediction by designing and conducting an experiment. • Hypothesizing that the best method for one class will be the best method for other classes. Testing hypothesis by repeating experiment in the other class. • Simulating learning activity when trying out materials. • See also SOCIAL SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses*.
Measuring/Collecting, Recording Data	• Conducting pretests, posttests, and retention tests on topic being learned by different methods or in different surroundings. • Measuring and recording length of time each group spends on learning the topic. • Measuring and recording the sound level intensity of the learning environment. • See also MATHEMATICS list: *Measuring*. • See also SOCIAL SCIENCE list: *Organizing, Processing Data*.
Organizing, Processing Data	• Using pretest scores to set up equal groups to use different learning methods. • Calculating the differences between pretest and posttest scores, between posttest and retention test scores. • Ordering the differences in scores from smallest to largest.

Organizing, Processing Data (cont.)	• See also MATHEMATICS list: *Measuring.* • See also SOCIAL SCIENCE list: *Organizing, Processing Data.*
Analyzing/Interpreting Data	• Finding the average amount learned for each group. Comparing these averages to determine which method is best. • Finding the median and middle range of the amount learned for each group. Comparing the difference in medians with the largest middle range to determine whether the differences among the groups are significant. • See also MATHEMATICS list: *Comparing; Statistical Analysis; Opinion Surveys/Sampling Techniques; Graphing.* • See also SOCIAL SCIENCE list: *Analyzing, Interpreting Data.*
Communicating, Displaying Data	• Showing data on charts and graphs. • See also MATHEMATICS list: *Graphing.* • See also SOCIAL SCIENCE list: *Communicating, Displaying Data.* • See also LANGUAGE ARTS list.
Generalizing/Applying Process to New Problems	• Applying skills learned in designing experiments to other experiments. • Using knowledge about noise level measurements to help solve other noise problems. • See also SOCIAL SCIENCE list: *Generalizing/Applying Process to Daily Life.*

Areas of Study

Measurement	• Measuring sound levels using commercial instruments. • Using timing devices to measure time spent on learning a certain topic. • Designing and constructing measuring devices as needed in learning a topic.
Sound	• Observing that sounds differ in tone, pitch, and loudness. • Observing that noise levels are lower when curtains or acoustical barriers are used to absorb the sound. • Observing that a sound becomes less intense as it moves away from its source.

Sound (cont.)

- Observing that sound readily travels around objects.
- Observing that different materials absorb sound to different degrees. Solid, dense materials tend to transmit sound well. Soft or porous materials tend to make better soundproofing because they absorb sound.

ACTIVITIES IN WAYS TO LEARN/TEACH UTILIZING SOCIAL SCIENCE

Process	
Observing/Describing/Classifying	• Organizing and classifying sets of ideas or information. • Classifying different ways to learn a certain topic. • Observing and describing reactions of other students when they are taught by different methods or in different environments. • Classifying and describing items to be included on the pretest, posttest, retention test. • See also MATHEMATICS list: *Classifying/Categorizing.* • See also SCIENCE list: *Observing/Describing; Classifying.*
Identifying Problems/Variables	• Identifying problems of regular learning procedures. • Identifying possibility that smarter students may all choose to work in the same group and therefore affect the average scores of the groups. • Identifying fact that a student's performance may vary depending on the learning method that is used for that individual. • Identifying possibility that the best methods to use in learning one subject may not be the best for learning another subject. • See also SCIENCE list: *Identifying Variables.*
Manipulating, Controlling Variables/ Experimenting	• Devising tests to measure how much progress is made with different ways to learn a certain topic. • Devising tests to determine how much is learned in different environments. • Asking another class to be the control group and learn the same topic according to the usual classroom procedure. • Establishing a random selection procedure for selection of group members. • Using pretest scores for selection of group members. • Repeating the experiment with students trying out another method or another environment. • Repeating the experiment, using the same methods or same environment to learn another subject. • See also SCIENCE list: *Manipulating, Controlling Variables/Experimenting.*

Inferring/Predicting/Formulating, Testing Hypotheses	• Predicting that one method or environment will produce more learning than other methods. • Inferring from survey and test data that most learning occurs when students use the methods they like best. • Hypothesizing that a certain method will produce better retention than other methods; giving another test after a period of time and comparing results. • See also SCIENCE list: *Inferring/Predicting/Formulating, Testing Hypotheses*.
Collecting, Recording Data/ Measuring	• Using a voting procedure to determine the ways of learning that are preferred by most students. • Conducting pretests and posttests on topic learned. • Counting number of worksheets or other materials they will need. • Conducting a second posttest to find whether the best learning method also produces the best retention. • See also MATHEMATICS list: *Measuring*. • See also SCIENCE list: *Measuring/Collecting, Recording Data*.
Organizing, Processing Data	• Tallying votes to select learning methods for their experiment. • Tallying survey or questionnaire data on preferred ways to learn. • See also MATHEMATICS list: *Organizing Data*. • See also SCIENCE list: *Organizing, Processing Data*.
Analyzing, Interpreting Data	• Comparing qualitative data gathered from surveys with quantitative data obtained from tests. • Evaluating survey methodology. • Evaluating results of group scores. • Comparing each person's performance for several methods. • See also MATHEMATICS list: *Comparing, Statistical Analysis, Opinion Surveys/Sampling Techniques*. • See also SCIENCE list: *Analyzing, Interpreting Data*.
Communicating, Displaying Data	• Representing survey data on bar graphs or charts. • Making graphs or charts that can be easily understood by the intended audience. • See also MATHEMATICS list: *Graphing*. • See also SCIENCE list: *Communicating, Displaying Data*. • See also LANGUAGE ARTS list.

Generalizing/Applying Process to Daily Life	• Using knowledge acquired from taking surveys about preferred learning methods to help solve other problems where attitudes are important. • Using knowledge acquired from finding the best way to learn a certain topic to find the best way to learn another subject. • See also SCIENCE list: *Generalizing/Applying Process to New Problems*.

Attitudes/Values

Accepting Responsibility for Actions and Results	• Making sure that various tasks are done, e.g., completing learning materials by designated deadline. • Scheduling times to teach another class. • Scheduling and giving presentations to persons in authority—for example, the principal and other teachers—to encourage the use of the best method to learn a certain topic.
Developing Interest and Involvement in Human Affairs	• Promoting changes in their usual methods of learning. • Encouraging other classes to use their suggested methods of learning.
Recognizing the Importance of Individual and Group Contributions to Society	• Recognizing that improving ways to learn a topic will help not only themselves but also other classes who use the techniques and future students in their teacher's class. • Recognizing that they can improve procedures in their classroom. • Assessing the effects of group action on learning procedures in the school.
Developing Inquisitiveness, Self-Reliance, and Initiative	• Conducting group sessions with help from the teacher. • Finding solutions to problems encountered in addition to the main problem of the challenge. • Finding the learning method that works best for each student. • Choosing and developing the best way of presenting a new topic to other students. • Choosing and developing the best way of presenting their teaching plans to another teacher.

Recognizing the Values of Cooperation, Group Work, and Division of Labor	• Finding that work on determining the best way to learn or to teach a topic progresses more rapidly and smoothly when they work in groups. • Eliminating needless overlap in work. • Finding that work is more fun and proceeds more smoothly when people cooperate.
Understanding Modes of Inquiry Used in the Sciences, Appreciating Their Power and Precision	• Using scientific modes of inquiry to investigate and determine the best way to learn or to teach a topic. • Using data, graphs, and other supportive material to convince other people that their proposed way to learn is a good one. • See also MATHEMATICS and SCIENCE lists.
Respecting the Views, Thoughts, and Feelings of Others	• Considering all suggestions and assessing their merits. • Considering the opinions of others when proposing a change in the usual learning methods used in class; conducting an opinion survey to determine preferred ways to learn a certain topic. • Respecting the thoughts, interests, and feelings of members of the opposite sex when working in groups.
Being Open to New Ideas and Information	• Considering alternative ways of performing various tasks. • Conducting library research to find information related to the topic to be learned/taught. • Asking other people for opinions, ideas, and information.
Learning the Importance and Influence of Values in Decision Making	• Recognizing that preferences for different learning techniques reflect the values of each individual.

Areas of Study

Political Science/Government Systems	• Establishing rules for conduct when new ways to learn are being taught to other students. • Getting in touch with and working with school principal and teachers to obtain permission to try out new ways to learn with other students.

Social Psychology/Individual and Group Behavior	• Recognizing need for leadership within small and large groups. Recognizing differing needs of individuals for various roles within groups. • Analyzing the effects of a small group making decisions for a larger group.
Sociology/Social Systems	• Devising a system of working cooperatively in small and large groups. • Working within established social systems to promote changes in learning procedures within the classroom, within the school. • Experiencing and understanding differences in social systems in different social groups (children, adults, women, men, homemakers). • Recognizing that there are many different social groups and that one person belongs to more than one social group.

ACTIVITIES IN WAYS TO LEARN/TEACH UTILIZING LANGUAGE ARTS

Basic Skills

Reading: Literal Comprehension--Decoding Words, Sentences, and Paragraphs	• Decoding words, sentences, and paragraphs while reading information relating to the topic being learned or taught, while reading test questions, while reading other people's writing.
Reading: Critical Reading--Comprehending Meanings, Interpretation	• Obtaining factual information about the topic being learned or taught. • Understanding what is read about the topic being learned or taught; learning the meaning of new words. • Interpreting what is read. • Following written directions.
Oral Language: Speaking	• Offering ideas, suggestions, and criticisms during discussions in small group work and class discussions on problems and proposed solutions. • Reporting to class about data collection, preparation of materials, graphing. • Responding to criticisms of activities; responding to questions. • Preparing, practicing, and giving effective oral presentations when teaching students in another class, when encouraging other teachers to use suggested learning method with their classes. • Practicing and preparing lessons to be tape recorded or videotaped. • Conducting opinion surveys. • Asking questions to obtain information; phrasing questions to elicit type of response desired. • Using rules of grammar in speaking. • Using new words in the proper context. • Explaining learning method when teaching other students.
Oral Language: Listening	• Interviewing other children to find best liked ways to learn a certain topic. • Following spoken directions. • Listening to group reports. • Listening to responses to one's questions.

Oral Language: Memorizing	• Memorizing portions of oral presentations to make when teaching other students. • Using memorization as one method for learning a new topic.
Written Language: Spelling	• Using correct spelling in writing reports, questionnaires, lessons, tests.
Written Language: Grammar--Punctuation, Syntax, Usage	• Using rules of grammar in writing reports, questionnaires, lessons, tests.
Written Language: Composition	• Writing to communicate effectively: • preparing written reports using notes, data, graphs, etc., communicating reasons for using new learning method. • preparing worksheets, scripts for a tape recording, directions for a game. • writing opinion surveys for other children; devising questions to elicit desired information. • devising tests; judging whether a question is relevant and whether its meaning is clear.
Study Skills: Outlining/Organizing	• Taking notes during class discussions, during research related to topic. • Developing opinion surveys; ordering questions around a central theme, such as preferred learning methods. • Planning presentations, data collection schemes, etc. • Planning and preparing reports and lessons for critical review by class. • Organizing ideas, facts, data for inclusion in reports, presentations, lessons.
Study Skills: Using References and Resources	• Using the library to research information about a topic to be learned. • Using dictionary and encyclopedia to locate information. • Using indices and tables of contents to locate information in books. • Using "How To" Cards for information on graphing, surveying.

Attitudes/Values

Appreciating the Value of Expressing Ideas Through Speaking and Writing	• Finding that classmates and teacher may approve of an idea if it is presented clearly. • Finding that learning is easier when ideas are presented clearly.
Appreciating the Value of Written Resources	• Finding that certain desired information about a topic can be found in library books. • Finding that written resources may provide an effective method of learning certain topics.
Developing an Interest in Reading and Writing	• Willingly looking up information about the topic being learned. • Looking up more detailed information. • Showing a desire to work on preparing written lessons, reports, surveys.
Making Judgments Concerning What Is Read	• Deciding whether what is read is relevant to the scope of the topic being learned. • Deciding on reliability of information obtained from reading. • Deciding whether written material is appropriate, whether it says what it's supposed to say, whether it may need improvement. • Distinguishing facts from opinions.
Appreciating the Value of Different Forms of Writing, Different Forms of Communication	• Finding that the best way to convey information is determined in part by the audience to whom it is directed; recognizing different needs of primary children and older students. • Finding that certain information can be best conveyed by writing it down, preparing charts or graphs, etc. • Finding that certain data or information should be written down so that it can be referred to at a later time. • Finding that spoken instructions are sometimes better than written instructions, and vice versa. • Finding that some people learn best by reading and others learn best by listening.